STEINMÜLLER

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DESIGN STUDY FOR PULVERIZED COAL BURNERS FOR THE COMBINED REDUCTION OF NITROGEN AND SULPHUR OXIDES AT CANADIAN FORCES BASE GAGETOWN, NEW BRUNSWICK

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Table of contents

1.	Introduction
2.	$DeNO_x/DeSO_x$ combustion technology
2.1	$DeNO_x$ burner concept
2.2	NO_x emission control
2.3	SO_x and other gaseous pollutants emission control
2.3.1	Theoretical considerations
2.3.2	Practical application
3.	Description of $DeNO_x/DeSO_x$ combustion plant
3.1	Coal mill performance
3.2	$DeNO_x/DeSO_x$ burner
3.2.1	Burner control system
3.3	Additive injection system
3.3.1	Additive storage
3.3.2	Additive feeding
3.3.3	Air supply
3.3.4	Additive injection control
3.4	Boiler retrofit work
3.5	Refractory work

STEINMÜLLER

4.	Scope of supply and services
4.1	Combustion system
4.1.1	Two Steinmüller staged mixing burners
4.1.2	Two combination gas-oil burners
4.1.3	Two flame detection systems
4.1.4	Burner control system
4.2	Additive storage and feeding system
4.2.1	Additive storage
4.2.2	Additive feeding
4.2.3	Air supply system
4.2.4	I & C package for additive feeding
4.3	Boiler retrofit work
4.4	Refractory work
5.	Technical data
5.1	Input data
5.2	Operational data
5.3	Design data
6.	Cost breakdown

STEINMÜLLER

The annexed drawings are :

1. de NO_x/de SO_x burner
   F3G36502
2. Arrangement of de NO_x/de SO_x burner
   F3G36501
3. Flow diagram additive injection system
   F4S52990
4. Arrangement of additive injection system
   F4H52991
5. Tube offsets for burners
   K1E23906
6. Burner refractory material
   Ba2E6569
7. Mill performance curve
   A51
8. Burner performance curve
   A52
9. Burner pressure loss
   A53
10. Tertiary air louvre position
    A54
11. Slide gate valve
    F4T50071
12. Fluidized conveying trough
    F4T50077
13. Pneumatic ejector
    F4T50078
14. Inlet branch
    F4T50109
15. Rotary vane feeder
    F4T50253
16. Pneumatic two way feeder
    F4T50829
17. Fuel control (coal)
    ICB01
18. Control mill air flow
    ICB02

STEINMÜLLER

19. Control Classifier temperature and mill air before mill
ICB03

20. Air control burners
ICB04

21. Control heavy fuel oil
ICB05

22. Control secondary air
ICB06

1. Introduction

In view of the shortage and substantial rise in prices of oil and gas, the general trend is again to alternative forms of energy, of which the immediate choice is coal. The growing use of coal, however, will further increase SO_x, NO_x, HCl and HF emissions, as well as producing inereased quantities of dust, unless effective measures are taken to reduce this nuisance.

Pollutants which are considered at the moment are essentially SO_x and NO_x and therefore both federal and local government regulations on NO_x- and SO_x-emissions for power station boilers force utilities and boiler manufactures to develop techniques which allow the operation of boilers in compliance with present and future regulations.

It has been shown by various international R&D programs that the most cost effective method to meet the NO_x and SO_x provision is an in situ method. The reduction of NO_x just by the modification of the combustion is well known and will be practiced nowadays successfully. The reduction of SO_x by modifying the combustion seems to be impossible, because the combustion of organic sulfur forming sulfurdioxide goes parallel to the formation of CO. Thus the only way of an in situ desulfurization is the injection of sorbents such as $Ca(OH)_2$ and $CaCO_3$ in the furnace.

A number of experimental studies are known which describe the desulfurization injecting the additives into the furnace in various ways.

With fluidised bed firing, where the additive is introduced mixed with the treated coal into the fluidised bed, it is possible to bind significant amounts of sulfur in the ash. Fluidised-bed firing is, however, a new technology which to some extent is still in the experimental stage; for this reason its commercial application especially in large power stations is likely to be a protracted business.

A desulfurization process for brown coal firing systems, in which the additive is mixed with the fuel before the latter reaches the burner, has been widely tested on a pilot plant scale with successful results. When similar processes were used in bituminous coal firing systems the degree of desulfurization achieved was markedly inferior. The reason for this is obviously the higher flame temperature, since the additives are subjected to the whole spectrum of flame temperatures and must traverse temperature bands which can decompose any sulfate compounds already formed and cause sintering of the surface of the additive particles.

Injection of additive above the flame region into the furnace by air jets has also been investigated in pilot plants. The results were considerably better than when the additive was mixed with the fuel. These processes only offer prospects of success in small boilers, however. The disadvantage inherent in the method is that the injection of the additive into the furnace demands very high energy on the part of the jets if good mixing of reactant and sulfur are to be attained. This is hardly practicable, particularly in the enormous gas flows of large units. Additionally, this mixing would tend mainly

to occur just in that portion of the boiler where temperature and residence time are at their most unfavourable for the reaction between additive and sulfur which results in the removal of the latter.

After a thorough analysis of the above-mentioned desulfurization processes and the technical problems involved, and because direct injection of additive is due to low investment costs such an attractive prospect, a process was developed which offered a much better chance of achieving the necessary preconditions for furnace sulfur removal in respect of temperature, mixing and residence time even for high calorific value fuels, and at an economic cost.

2. $DeNO_x/DeSO_x$ combustion technology

2.1 $DeNO_x$ burner concept

As Fig. 1 shows the SM-burner is derived from the reliable circular swirl burner. The pulverized coal is fed to the burner throat by an annular fuel gun and injected concentrically to the burner axis.

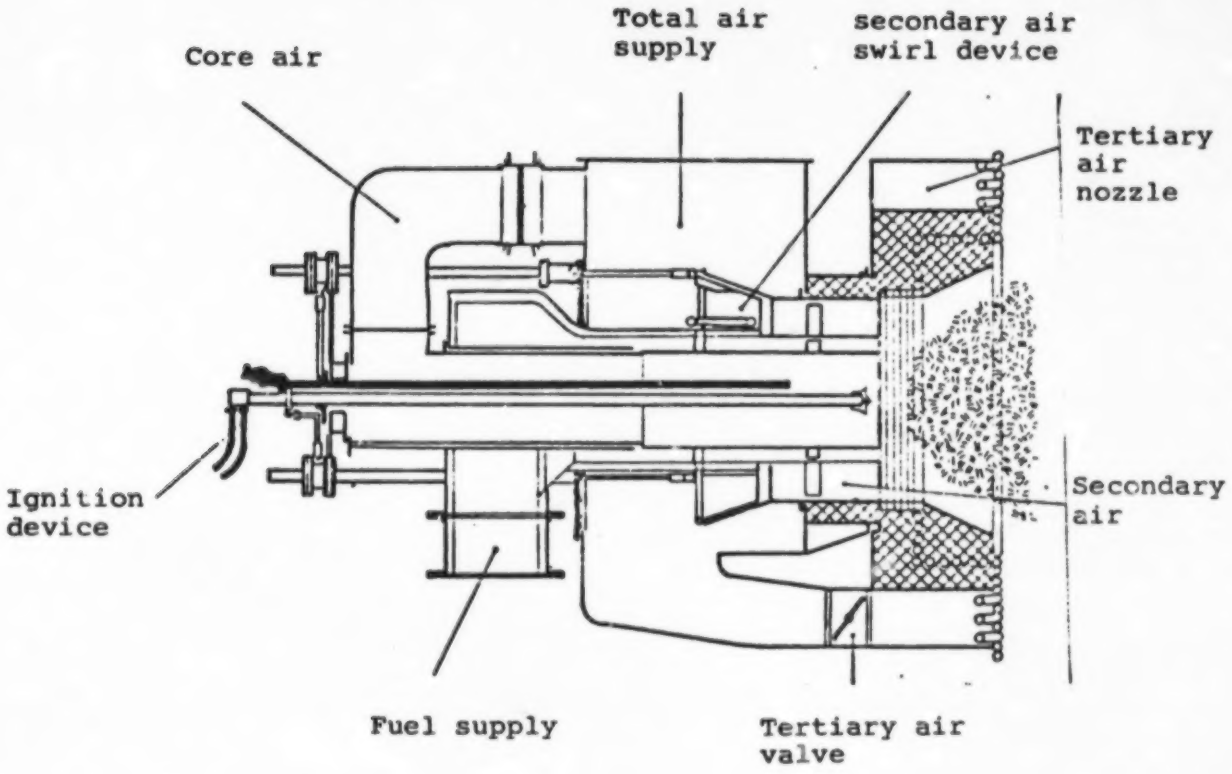


Fig. 1: Staged mixing burner (SM-burner)

The former secondary air is now split up into two streams, a reduced secondary air flow which is passed as usual through the annular air duct surrounding the fuel gun, and a tertiary air flow to four tertiary air nozzles which are placed concentrically about the burner quarl exit. The additives, e.g. $Ca(OH)_2$ or $CaCO_3$, are introduced via nozzles arranged concentrically about the burner quarl exit in a manner to produce an additive film around the flame. The additive nozzles could be placed in the staging air pipes, which are located concentrically about the axis of the burner at a distance twice that of the secondary air pipe or even larger, the additive-laden

staging air is thus made to reach the flame proper outside the temperature zones in which the activity of the additives is reduced.

At 100 % coal firing the core air butterfly valve is almost closed. It is adjusted in such a way that just sufficient core air is passed through the central duct to avoid recirculation flows induced by the swirling secondary air into the core air duct.

A variable swirl device allows a control of the secondary air swirl intensity.

The tertiary air quantity, respectively the tertiary/secondary air ratio, can be controlled by the butterfly valve in the tertiary air duct.

To control the overall burner stoichiometry, the total air flow to each burner is measured individually.

2.2 NO_x emissions control

Numerous studies of theoretical and experimental nature have shown that the emission of oxides from p.f. systems can be accredited in essence to two original causes:

- Thermal NO_x formation evolving from the oxidation of nitrogen which, at least prior to the onset of the combustion reaction, is present in molecular form, e.g. atmospheric nitrogen. This reaction heavily depends on the temperature.

- Fuel NO_x formation evolving from the oxidation of fuel bound nitrogen. Because of the inherently lower energy of activation, NO_x oxidation might result already under a fairly low temperature environment when nitrogen-carbon compounds are formed in the course of combustion. Hence, this reaction foremost depends on the oxygen concentration in the reaction zone.

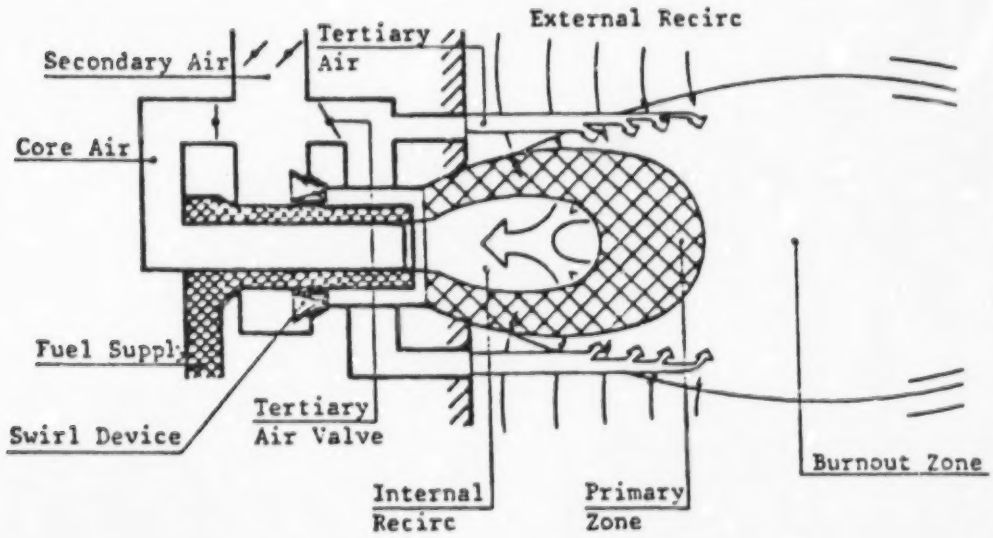


Fig. 2: SM-burner schematic with anticipated flow and mixing regime

In the staged mixing burner, as proposed by us, combustion proceeds as shown in Fig. 2.

Backed by the pulverized-fuel/air mixture and the secondary air, a sub-stoichiometric primary combustion zone is created in close vicinity of the burner throat.

Our experimental and theoretical investigations have confirmed that the air ratio dominant in that region represents the salient NO_x-sensitive parameter.

By virtue of the described design features, ignition becomes intense and combustion so accelerated that de facto an air deficiency occurs which causes a reduction of fuel-linked nitrogen compounds to molecular nitrogen. To ensure complete combustion, staging air in the form of a few single jets is nozzled into the burnout zone.

By the single-jet configuration sufficient momentum of the jets is retained so that even at some distance from the burner throat intimate mixing of air with the burnout zone is afforded and no sensible flame lengthening will occur.

In view of the fact that the primary zone reaction products already release heat before being finally burned out in the secondary flame zone, the flame temperatures in that zone can be expected to be lower than with non staged mixing. Besides that the outer recirculation of flue gases into the flame, exerting a temperature-reducing effect, will be intensified. This will not only reduce fuel NO_x-formation but also thermal NO_x-formation.

The momentum ratio of secondary air to primary air has been selected to provide for a satisfactory flame pattern, i.e. besides flue gas recirculation, also flue gases from the furnace are absorbed by the flame. Flue gases stem from the totally burned out region of the flame and in their chemistry they correspond to the set mean excess air. Hence, it is ensured that all the furnace walls, including the burner zones, come into contact only with burned out flue gases.

2.3 SO_x and other gaseous pollutants emission control

2.3.1 Theoretical considerations

The release of the heat of combustion locked up in fossil fuels is almost exclusively accomplished by combustion processes at temperatures up to 2000 °C. The enthalpy chemically bound within the fuel is thereby transformed into the enthalpy of the products of combustion.

When coal is burned, the products mainly consist of carbon dioxide, water vapour, nitrogen and excess oxygen. But there are also unpleasant sideproducts: the pollutants HCl, HF, NO_x, SO_x and dust. One can assume with fair certainty that the oxides of nitrogen and sulfur are present in the flue gas predominantly as NO and SO_2. The amount of NO_2 and SO_3 is very slight.

It is known that the formation of oxides of nitrogen can be reduced at least 50 % by careful control of combustion. But since the formation of sulfur dioxide, hydrogen chloride and hydrogen fluoride takes place parallel to that of carbon monoxide, the only way of removing these pollutants from the flue gases and thus reducing emissions is to absorb them chemically after they have been formed.

When $Ca(OH)_2$ or $CaCO_3$ is added to bind these pollutants, the additives themselves are dehydrated or decarbonated (calcined) in the furnace according to the following reactions:

$$Ca(OH)_2 \longrightarrow CaO + H_2O \qquad (1)$$

$$CaCO_3 \longrightarrow CaO + CO_2 \qquad (2)$$

The chemical binding of the pollutants in the furnace and downstream of it is effectively a series of heterogenous gas/solid reactions which develop under a constant gas pressure slightly under normal atmospheric pressure. The individual preactions with the pollutants can be expected to be as follows:

$$CaO + SO_2 + 1/2\ O_2 \longrightarrow CaSO_4 \qquad (3)$$

$$CaO + 2\ HCl \longrightarrow CaCl_2 + H_2O \qquad (4)$$

$$CaO + 2\ HF \longrightarrow CaF_2 + H_2O \qquad (5)$$

$$CaO + SO_3 \longrightarrow CaSO_4 \qquad (6)$$

The reaction enthalpies show that dehydration and decarbonation are endothermic reactions and all the reactions with pollutants are exothermic. In Fig. 3 reaction enthalpy of reactions (1) - (6) is shown as a function of temperature . With increasing temperature the reaction enthalpy decreases slightly.

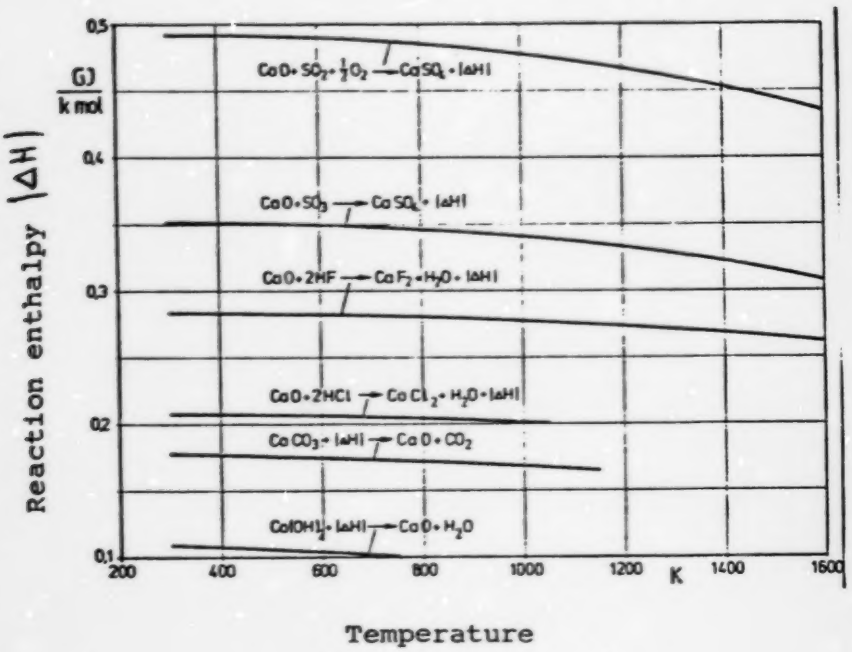


Fig. 3 : Reaction enthalpy as a function of temperature

The standard enthalpies (298.15 K and 1.013 bar) of reactions (1) - (6) are as follows:

Reaction No.	Standard Enthalpie kJ/kmol	kJ/kgCaO
1	109300,0	1951,8
2	177400,0	3167,9
3	- 492000,0	- 8785,7
4	- 207900,0	- 3712,5
5	- 283700,0	- 5066,1
6	- 351000,0	- 6267,9

Since the proportion of sulfur in the coal, compared with that of chloride and fluoride, is much higher, the greater part of the calcium is employed in binding the sulfur. If the thermal energy required to form CaO (as detailed in the preceding table) is now compared with the thermal energy set free by the exothermic sulfation reaction it will be apparent that, in order to completely regain the energy lost by dehydration and/or decarbonation, a calcium efficiency of 22 % and/or 36 % is necessary. The calcium efficiency is defined as the percentage of injected calcium which is stoichiometrically required to react with the amount of removed SO_2.

In order to obtain some indication whether the reactions listed tend of their own volition to move in the desired direction from left to right, their equilibrium constants are represented in Fig. 4 as a function of temperature.

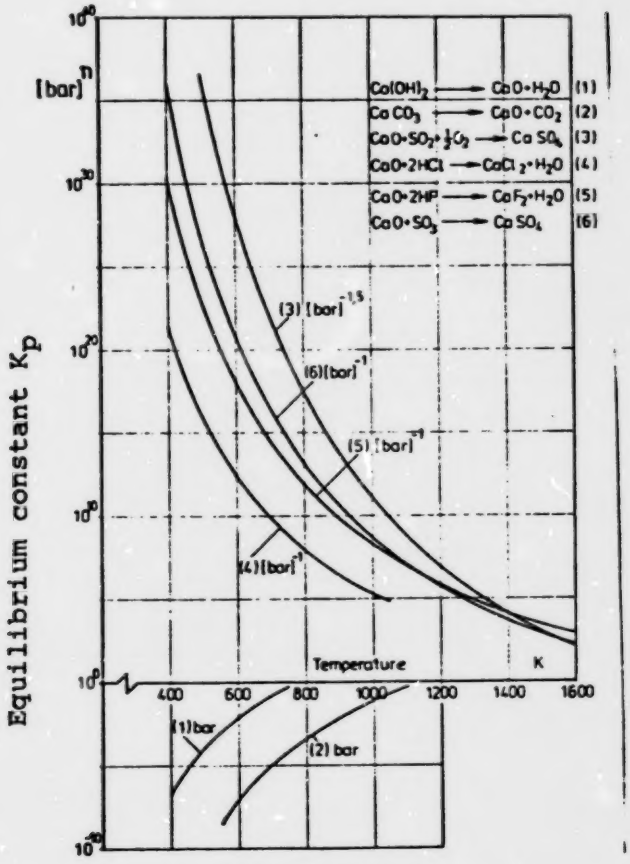


Fig. 4 : Equilibrium constant as a function of temperature

Instead of the actual situation where the equilibria of these reactions are mutually interdependent, it has been simplified the case for better clarity and examine the equilibrium constants for each reaction separately. The laws of chemical thermodynamics state that a reaction only proceeds of its own volition when the equilibrium constant K_p is greater than unity.

According to this, as can be seen from Fig. 4 the reactions combining the gaseous pollutants in the furnace will still occur freely at high temperatures, but the affinity of the reactions decreases with increasing temperature. Reactions (1) and (2) do not proceed of their own volition.

Fig. 5 shows the equilibrium curves of reactions (1) and (2), which demonstrate the relation between the partial pressures of the gaseous elements, water vapour and carbon dioxide as a function of temperature for the case of a reaction in equilibrium.

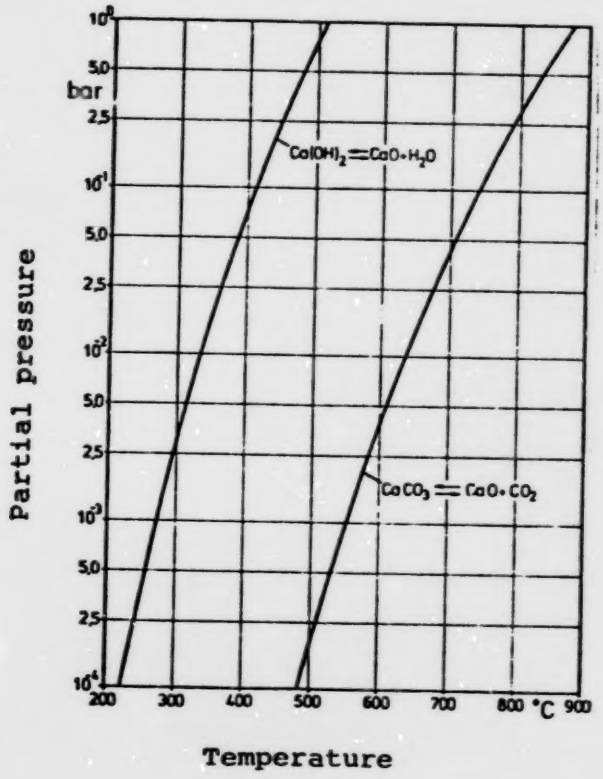


Fig. 5 : pT-curve for dehydration and decarbonation reactions

As the curves show, the equilibrium partial pressures increase with rising temperatures. The numerical values for the partial pressures of H_2O and CO_2 diverge however very sharply. Assuming a water vapour content of 5 % and a CO_2 content of 15 % in the flue gas, dehydration would take place at about 400 °C and decarbonation at around 750 °C.

In Fig. 6 the partial pressure of SO_2 is shown as a function of temperature for oxygen contents in the flue gas of 1 % and 6 %. The equilibrium curve reveals that, for a given SO_2 partial pressure, it is possible to draw conclusions about the likelihood of stable sulfur dioxide absorption at the flue gas temperatures obtaining in the furnace.

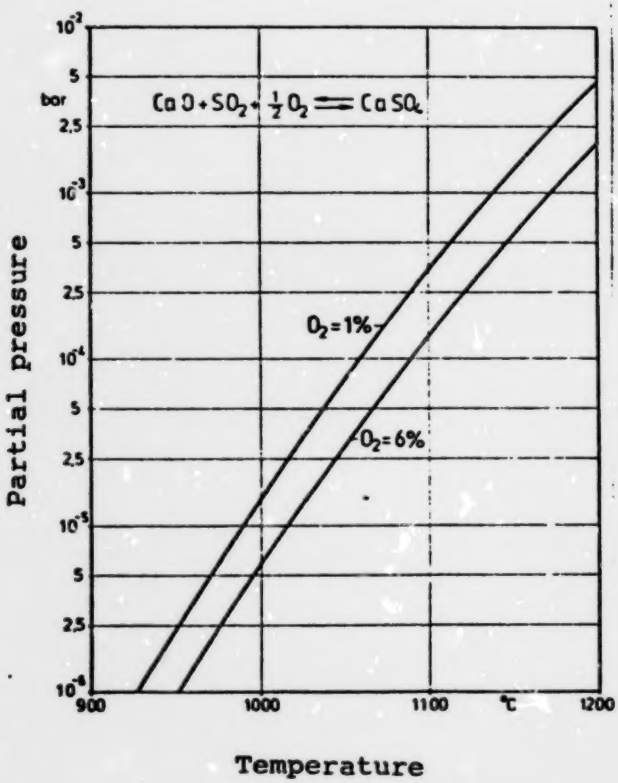


Fig. 6 : pT-curve for sulfation

The binding of sulfur as in reaction (3) would then be possible when the flue gas temperature falls below the equilibrium temperature as renealed by the equilibrium curve. At a total pressure of 1 bar and oxygen level of 6 % in the flue gas, the equilibrium temperature for 1000 ppm SO_2 concentration comes out to be 1170 °C.

Fig. 7 shows the equilibrium pressure curves for the binding of HCl and HF at 5 % and 20 % water vapour contents respectively in the flue gas.

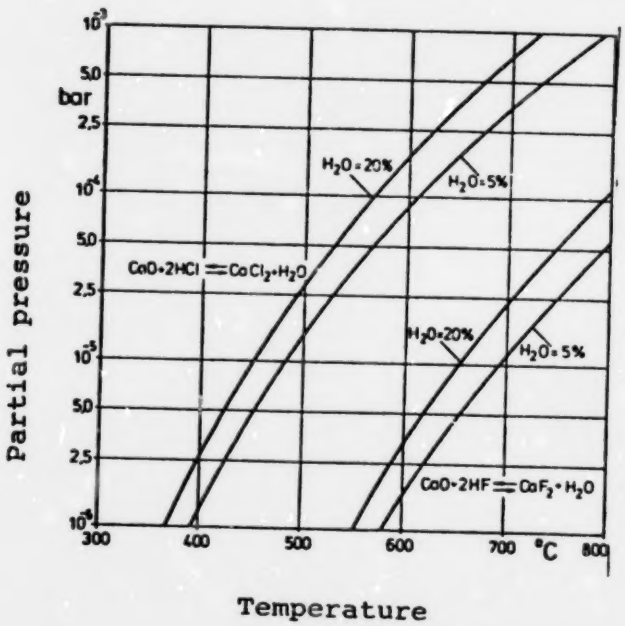


Fig. 7 : pT-curve for chloride and fluoride absorption

As the partial pressure of the pollutant rises and the water vapour partial pressure in the flue gas sinks, the equilibrium temperature rises. At a total pressure of 1 bar and flue gas moisture content of 5 %, the equilibrium temperature for an HCl concentration of 100 ppm is about 600 °C. Similarly, for an HF concentration of 10 ppm the equilibrium temperature is around 700 °C.

The equilibrium pressure curve of SO_3 binding as in reaction (6) is shown in Fig. 8. At a total pressure of 1 bar the equilibrium temperature for an SO_3 concentration of 40 vpm (143 mg/m^{3}n) is 1050 °C.

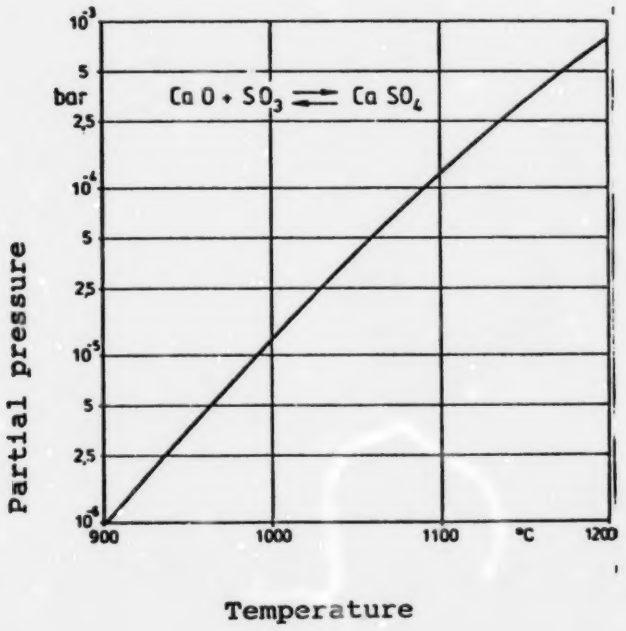


Fig. 8 : pT-curve for SO_3 absorption

These considerations based on chemical thermodynamics reveal that, given thorough mixing with the flue gases and no sintering of the additive surface, binding of pollutants within the furnace is possible. Whether a reaction which is thermodynamically possible actually proceeds with the necessary speed, however, is a question of reaction kinetics and can not be anscured by the lanes of thermodynamics.

Data on the kinetics of the reactions quoted are somewhat thin on the ground. However there are some laboratory experiments done in the sixties are available to determine the relationship between temperature and degree of desulfurisation. The results of this work are presented in Fig. 9. From them we can see that $Ca(OH)_2$ is more effective as an additive than CaO and demonstrates its maximum binding capacity for sulfur in the temperature range 800 °C - 1100 °C.

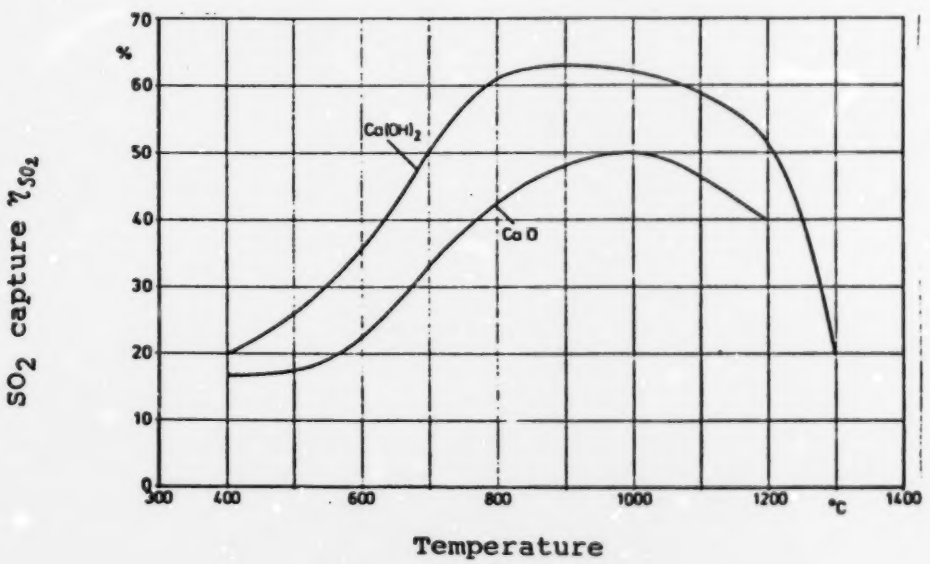


Fig. 9 : SO_2 Capture as a function of temperature

Thus, in spite of the lower affinity of the binding reaction at higher temperatures (Fig. 4), it is obvious that, thanks to the increased speed of reaction, a high degree of absorption is still possible even at these higher temperatures.

These theoretical studies show that, the in situ desulfurization is possible via injecting the sorbents in the furnace. The inportant is to mix the sorbents well with the flue gas and avoid the sintering of the additive surface, which starts in the case calciumoxide at about 1250 °C.

2.3.2 Practical application

The staged mixing burner (SM-burner) developed by Steinmüller to reduce NO_x formation offers, compared to earlier circular burners, a better possibility to inject the sorbents with the staging air in the furnace as shown in Fig. 10. With the help of SM-burner the three important conditions to capture the sulfur and other pollutants can be realized, and these are: proper temperature, well mixing and sufficient residence time.

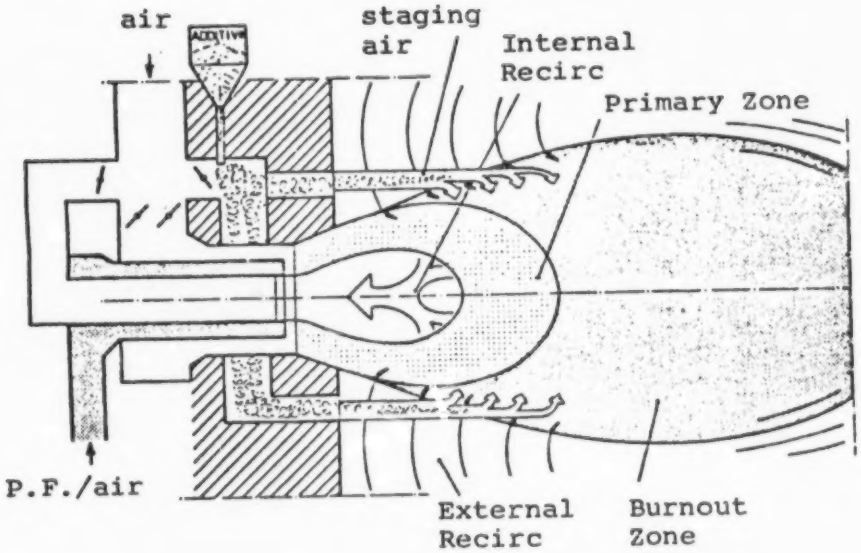


Fig. 10 : SM-burner with additive injection

The additive does not pass through the high temperature flame zones, so that the sintering of the additive can be avoided. Due to high turbulence around the flame the mixing of the additive with the flue gas is optimum. Even avoiding the mixing of the additive with the fuel, the practically total residence time from the burner up to the ESP is available to absorb the pollutants.

3. Description of $DeNO_x/DeSO_x$ combustion plant

3.1 Coal mill performance

As shown in the drawing F3G 36501 the coal is pulverized and dried in two existing Raymond mills. For the purpose of mill drying, preheated air is mixed with flue gas drawn fram the lower section of the furnace.

Each burner is served by one mill. The mixture of dried coal, water vapours, air and flue gas is taken directly to the burners by an exhauster fan.

To warrant reliable operation of the $DeNO_x/DeSO_x$ burners, the mill performance figures as per Fig. A51 must be observed. In this diagram the mill load has been plotted as a function of the air and flue gas flows as well as the mill inlet temperature.

3.2 $DeNO_x/DeSO_x$-burner

As shown in the drawing F3G 36502, the staged mixing burner (SM-burner) is derived from the reliable circular swirl burner. The pulverized coal is fed to the burner throat by an annular fuel gun and injected concentrically to the burner axis. The combustion air supply is split up into secondary air and staging air, as shown in Fig. A 52. The pressure drop across the burner on the primary and secondary air side is illustrated in Fig. A53. The secondary air flow is injected through the annular air duct surrounding the fuel gun.

Axially passing a moveable swirl device, the secondary air is given a swirl, the intensity of which can be adjusted within defined limits. Core air is added only when burning oil, but remains practically closed while firing coal. A dampercontrolled portion of staging air is taken from the common air supply to one burner.

The staging air damper setting as a function of supply pressure to damper and burner load can be gathered from Fig. A54. The staging air is injected into the flame via nozzles arranged concentrically about the burner quarl exit. By appropriate staging air control a constant momentum flow ratio of secondary to primary air is obtained over the burner operating load.

The coal enters the burner at the bottom and is deflected in the substantially diverging head portion. The markedly decelerated flow will eliminate pulverized fuel (p.f.) stratifications. On account of the converging cross-section from p.f. head to p.f. pipe, the flow is again accelerated thereby enforcing a renewed homogenous p.f./air distribution in the flow. All parts exposed to severe wear will be of a solid design.

The burner tip is manufactured of a high temperature material with 23 % chromium and 20 % nickel.

Special attention has been paid to the question of locally stable ignition as basis for safe and reliable burner performance by implementing the following design features:

- Hopper shaped divergence of burner throat
- Adjustable swirl of secondary air
- Core air pipe which remains almost inoperative during coal firing.

In consequence, in the core region of the flow effluxing from the burner there results an underpressure which sets up a pressure gradient towards the burner mouth thereby promoting an inner recirculation of hot flue gases from an advanced combustion zone. The recirculation flow directly carries to the coal dust the heat required for ignition so that same becomes self-sustaining by the flame proper and does not have to rely on heat from any contiguous flames in the furnace.

By virtue of the described design features, ignition becomes intense and combustion so accelerated that de facto an air deficiency occurs which causes a reduction of fuel-linked nitrogen compounds to molecular nitrogen. To ensure complete combustion, staging air in the form of a few single jets is nozzled into the burnout zone.

By the single-jet configuration sufficient momentum of the jets is retained so that even at some distance from the burner throat intimate mixing of air with the burnout zone is afforded and no sensible flame lenghtening will occur.

In view of the fact that the primary zone reaction products already release heat before being finally burned out in the secondary flame zone, the flame temperatures in that zone can be expected to be lower than with non-staged mixing. Besides that, the outer recirculation of flue gases into the flame, exerting a temperature-reducing effect, will be intensified. This will not only reduce fuel NO_x-formation but also thermal NOx-formation.

The momentum ratio of secondary air to primary air has been selected to provide for a satisfactory flame pattern, i.e. besides flue gas recirculation, also flue gases from the furnace are absorbed by the flame. Flue gases stream from the totally burned out region of the flame, and in their chemistry they correspond to the set mean excess air. Hence, it is ensured that all the furnace walls, including the burner zones, come into contact only with burned out flue gases.

To any non-firing burner is delivered a purging air flow of some 5 % of the requirement at maximum combustion rate for the purpose of preventing any flows that carry hot flue gases from the furnace into the burner and unduly heat components of the burner not directly exposed to thermal radiation.

The additives, $Ca(OH)_2$ or $CaCO_3$, are introduced via nozzles arranged concentrically inside the staging air ports. The additve-laden staging air is thus made to reach the flame proper outside the temperature zones in which the activity of the additives is reduced.

The gaseous pollutants emitted in the combustion process i.e. SO_x, HCl and HF, are partly retained by the sorbent and separated together with the ash in the electrostatic precipitator.

3.3 Additive injection system

3.3.1 Additive storage

As shown in the drawing F4H 52991, the additive $Ca(OH)_2$ or $CaCO_3$ is stored in a 100 m^3 bin. Filling of the bin from the truck will be accomplished via a feed line allowing truck connection externally of the boiler house. The necessary transport is generated by the truck-mounted compressor.

Visible and audible alarm features are incorporated at the truck connection to display the maximum filling level. So that the filling process does not have to be stopped, with the truck only half emptied, the "max." level has been set to leave a residual volume of 20 m^3.

Aeration modules are fitted in the bin hoppered section for fluidizing the additive supply. The outgoing air, namely transport air from the truck, fluidizing air and air for the pneumatic feeder, is filter-cleaned and exhausted outside the boiler house.

The bin rests on weighing cells to establish the actual filling weight. The respective weight readings are obtained by analog display of signals from the weighing cells. The minimum filling level is indicated visibly in the control room.

3.3.2 Additive feeding

Additive feeding system is schematically shown in the drawing F4S 52990. Additive from the storage bin is taken by a pneumatic feeder to a rotary feeder which is arranged for variable-speed control as a function of the boiler load. The end speed of the rotary feeder is variable in four stages, allowing stoichiometric operation at factors 1, 2, 3 and 4.

Catering for the high difference in bulk density of the two additives, the rotary feeder can be operated with two different sets of internals so that the rotary feeder speed need not be adjusted separately as a function of the boiler load. The internal hardware is optimally tailored to the two additives in terms of number and volume of the chambers. The internals can be substituted without having to disassemble the drive unit.

An ejector draws the additive from the rotary feeder, delivering it via a conveying line to a distributor where the additive-air mixture is divided into eight equal volume flows. Four feed lines are provided for each burner. Line isolation will be by blanking discs.

3.3.3 Air supply

The required air supply is generated by two rotary compressors which are soundproofed and placed close to the end-use equipment. One of the compressors delivers air for the bin fluidization system and the pneumatic feeder, whilst the other compressor is operated at an appropriately higher discharge pressure to serve the additive feeding system. The distribution of air to bin and feeder is damper-controlled.

Air for additive feeding is metered across a venturi and indicated by analog display. Air flow rate adjustment can be effected by means of the downstream damper.

Motor polechanging on the rotary compressor for the additive feeding system is accomplished by reducing the transport air flow when one burner is out of service. In this way an abnormally high pressure drop due to excessive velocities in the conveying lines is prevented.

3.3.4 Additive injection control system

According to drawing F4S 52990 once gate valves V5 - V11 have been opened by hand, the silo fluidization unit G2 can be engaged. Subsequently, - with gate valve V3 open -, transport air fan G1 will be started.

As soon as these start-up criteria have been met, the rotary vane feeder can be taken into operation, four speed control ranges being open to choice by manual preselection.

If the pressure in the additive conveying line is exceeded or fallen short of, additive gate valve V3 is automatically closed and the vane feeder stopped.

3.4 Boiler retrofit work

Retrofitting the existing furnace to $DeNO_x/DeSO_x$ firing will necessitate a number of modifiactions on the burner-zone wall.

According to the drawing KlE 23906 the cooling tubes must be offset by bending to suit the new ports for staging air. The existing burner holes in the front wall will be used for retrofitting.

With regard to burner suspension it is assumed that there will be no differential expansion between boiler and boiler wall. The existing common air supply system will be modified for the $DeNO_x/DeSO_x$ burners by taking spur ducts, arranged for individual air flow metering, to each burner.

The proposed retrofit measures make it necessary to remove the burner wall refractories. When burners and pipes have been installed, a refractory setting is fitted to suit the conditions in situ.

3.5 Refractory Work

The refractory work is shown in the drawing Ba2E 6569. The conical burner throat will be made up of shaped bricks (70 % Al_2O_3), the vault-shaped bricks being fitted with cast chromium steel holders to prevent them from slipping out. For the setting of the bricks, a refractory mortar adequate for the brick quality involved will have to be used.

The steel components of the burners are sealed off against the bricks with ceramic fibrous material.

The wall brickwork surrounding the burners will be in firebrick quality A 30 t, vault shapes as well as groove and tongue plates being employed for the connection to the burners.

As backing between the firebricks and the sheet metal casing, insulating bricks 'Moler 500' and mineral wool slabs will be provided for.

4. Scope of supply and services

4.1 Combustion system

4.1.1 Two Steinmüller staged mixing burners

Each comprising:

Core air section with protective tube for oil gun, also complete with ignitor gun.
Primary air section with renewable chilled cast iron liners to armour the p.f. inlet head.
Secondary air section with swirl vane assembly arranged for axial adjustment.
Staging air section with ON-OFF damper and bracket for mounting actuator.

Nozzles for additive injection into the furnace, concentrically arranged in the staging-air pipes complete with flange for connecting transport line to distributor.

Core air connection to the common air supply to burner, inclusive of isolating damper, bracket and actuator.
Burner tips manufactured in special heat-resisting steel.
Burner quarl, lined with special high-grade refractory mass (approx. 72 % AL 203).
Replacing part of the p.f. pipes to the burners.

Manifold line for primary and secondary air.
Secondary spur lines from manifold line to burner, inclusive of:
Expansion joint, damper, actuator and airfoil section.
Primary air line with airfoil section.

4.1.2 Two combination gas-oil burners

Designed as a push-in package for insertion in the core-air section; each comprising:

Air-atomizing oil gun, mounted centrally in the gun protective tube, with impeller as well as oil and air hoses,

Pneumatic oil gun retract mechanism,

Electric gas-ignitor arranged for ionisation monitoring, with high-voltage ignition transformer and accessories, ignitor fitted in the protective tube, as well as hoses for ignition gas and air supply,

U.V. flame detection equipment, inclusive of amplifier and analog display,

Set of fittings for connection of PF burner.

4.1.3 Two flame detection systems

For gas/oil and coal firing, to include:

Flame detector, working on a change-over U.V. infrared flame frequency basis for oil/PF flames, with controllable amplification when changing from mixed oil-coal firing to exclusive PF operation.

Control unit with plug-in rack for mounting in local control cubicle (supplied by others).

Sheathed special cabling, approx. 20 m long, to connect flame detector and control unit.

4.1.4 Burner control system

- Combustion air control

The staged-mixing burner supplies air to the flame from three positions:

primary air with pulverized fuel
secondary air
staging air with additives

The secondary air regulating damper controls the secondary air flow as a function of load.

The staging-air regulating damper controls the staging air flow as a function of load. The staging-air share of the whole air flow per burner is different depending on whether the plant operates on p.f. or on oil. For dual fuel firing - p.f./oil - in a burner, the stging air is controlled just as in operation on p.f. only.

On principle, the staging air regulating damper is opened depending on load. However, since the combustion air flow - due to the staging air at a certain damper opening position - depends on supply pressure and temperature, the opening position of the staging air damper must be corrected in accordance with these two parameters.

The evaluation of the damper position, depending on whether p.f. or oil is fired, must be carried out separately for each burner.

Secondary air and staging air together flow to the burner. Core air is taken from secondary air.

Installed in the combustion air line to the burner is a flow metering nozzle; it measures the total of secondary air and staging air.

The core air damper is switched to two different positions:

oil firing (or dual fuel firing - oil/p.f.)
p.f. firing

When the burner is not operative, the core air damper is in position "oil firing". Control schematic is shown in the diagram ICB 06.

- Fuel control for p.f. in accordance with control schematic diagram ICB 01.

- Primary air control. in accordance with control schematic diagram ICB 02. As a special feature in this case, flue gas feeding into the primary air should be mentioned. When a minimum temperature is reached at mill inlet, the flue gas damper is opened and flue gas is mixed with the primary air to heat up the latter. At the same time primary air supply is reduced, which is caused by set point change-over of the closed-loop control system.

- Classifier outlet temperature control in accordance with control schematic diagram ICB 03.

- Combustion air control: arrangement in accordance with control schematic diagram ICB 04.

- Fuel control for oil in accordance with control schematic diagram ICB 05.

4.2 Additive storage and feeding system

4.2.1 Additive storage

1 Hinged closure DN 80,
manually operated

Truck delivery line, comprising:

12 lin. m steel piping 88,9 x 5,6
2 Steel elbows 90°, radius = 1000, DN 80,
with cast-basalt lining

1 Steel piping, 2000 lg. DN 80,
with cast-basalt lining

1 Steel piping, 1000 lg. DN 80,
with cast-basalt lining

1 Inlet connection DN 80, as per F4T 50109

1 Bin 100 m^3 net capacity, constructed of
6.5 and 4 mm plates, complete with inspection
part, top peripheral railing and access ladder

1 Sectional-steel structure, designed to
accommedate the bin and load cells

3 Electro-mechanical load cells with thrust pad,
overload protection and analog weighing unit
with display of net weight

2 Capacitance level switches for "min." and "max." contact

1 Negative-positive pressure flap to protect bin against over- and under-pressure loading

Aeration of bin bottom section, to include four fluidization modules, size 200 as per F4T 50077, complete with fabric pads

1 Bin extract-air filter 28 m^2 surface; filter material: polypropylene; including motorized rapping mechanism

1 Radial fan for extracted air, complete with coupliung and motor

2 Bin slide gate valves, size 350 as per F4T 50071, 1 off with direct flange-mounted geared motor with coupling and handwheel.

4.2.2 Additive feeding

1 Pneumatic feeder, size 350, comprising inlet and outlet boxes of 5 mm plate, flat steel stiffeners and flanges, air connections, wire netting and fabric pads

1 Rotary feeder, size 200 as per F4T 50253, with replaceable internal hardware as well as variable-speed glared motor with forced ventilation

1 Pneumatic ejector, size 250 as per F4T 50078 with nozzle and diffusor (replaceable) of chilled cast iron

Diverse connecting chutes of 5 mm plate

Conveying line, to include:

12 lin. m steel piping 88.9 x 5.6

4 Elbows 90°, DN 80, radius = 1000 mm, with cast-basalt lining

4 Straight pipes DN 80, 2000 mm length, with cast-basalt lining

1 Straight pipes DN 80, 1500 mm length, with cast-basalt lining

1 8-fold distributor of 4 mm plate

8 Connecting lines from distributor to burners, comprising lin. m steel piping 51 x 5.6, with wear-resistant elbows, flanges and fasteuers

8 Blanking discs DN 40.

4.2.3 Air supply

1 Rotary compressor to generate the required transport air, with multi-speed drive motor, V-belt transmission, forceventilated acoustic cowl, suction and discharge silencers

1 Rotary compressor to generate the required fluidizing air, with drive motor, coupling, force-ventilated acoustic cowl, suction and discharge silencers

1 Venturi flow-metering section with analog display of pressure differential

Air lines, to include:

2	lin. m steel piping	88.9 x 3.2
4	lin. m steel piping	70 x 2.9
5	lin. m steel piping	57 x 2.9
10	lin. m steel piping	51 x 2.6
2	lin. m steel piping	30 x 2.6

All lines supplied with bends, flanges, valves and fastenings for attaching to the existing steelwork.

4.2.4 I & C package for additive feeding system

Instrumentation

Weight measuring instruments for additive silo:
- Transmitters, contained in the Mechanical Part of supply
- Indicator

Rotary vane feeder speed - SIC
- Transmitters, contained in the Mechanical Part of supply
- 2 indicators, each for two different speeds
- Change-over switch

Transport air flow rate
- Differential pressure transmitter
- Triplex valve set
- Flow rate transducer
- Indicator

Local instruments such as pressure gauges, thermometers, pressure and level monitors contained in the Mechanical Part of supply.

Open-Loop Control

Relay-based control system for 5 drives.

Switchgear

Contactor framework for the drives of the following equipment:

- 1 silo extracted-air filter, 0.18 kW
- 1 extracted air fan, 0.95 kW
- 1 rotary vane feeder, 0.25 kW
- 1 fludization air fan, 3.0 kW
- 1 transport air fan, 18.5/12.0 kW
- 1 additive gate valve, 1 kW.

Closed-Loop Control

We proceed from the assumption that the load controllers will be client's responsibility.

Control Cubicle

Steel plate cubicle, Type of Enclosure IP 54, accommodating all measuring and open-loop control instruments as well as drives and actuators specified above. The annunciators required for the signalling system are likewise incorporated.

Installation work and material, assuming a mean distance of 30 m between control cubicle and instruments.

4.3 Boiler retrofit work
According to the drawing No. K1E 23906

4.4 Refractory work
According to the drawings No. B92E6569

STEINMÜLLER

5. Technical data

5.1 Input data

Number of burners	2
Capacity of each burner	12.5 MW

Boiler operation: 100 % load with both burners
50 % load with lower burner

Coal analysis

a) Proximate:

Moisture	%	10
Volatile matter	%	30
Fixed carbon	%	51
Ash	%	9
Net calorific value	MJ/kg	28.78
Spec. air requirement	kg/kg	9.20

b) Ultimate:

Carbon	%	75.2
Hydrogen	%	4.8
Sulfur	%	3.0
Nitrogen	%	1.4
Ash	%	10.0
Oxygen (diff.)	%	5.6

c) Sulfur forms:

Sulfate	%	0.4
Pyrite	%	1.8
Organic (diff.)	%	0.8

STEINMÜLLER

5.2 Operational data

Temp. after mill	°C	90
Temp. before mill	°C	272
Hot air temp.	°C	180
Gas/coal ratio	kg/kg	1.5
Excess air ratio		1.25
Total fuel flow rate	kg/s	0.868

Additive data:

Range of molar ratio	Ca/S	1 to 4
Flow range	$Ca(OH)_2$	4.61 l/min - 36.9 l/min.
	$CaCO_3$	2.48 l/min - 19.85 l/min.

CaO content of $Ca(OH)_2$	74 %
CaO content of $CaCO_3$	55 %

Specific surface area

$Ca(OH)_2$	1.86 m^2/g	(Blaine)
	14.8 m^2/g	(BET)
$CaCO_3$	0.456 m^2/g	(Blaine)
	1.45 m^2/g	(BET)

Bulk density:

$Ca(OH)_2$	400 kg/m^3
$CaCO_3$	1000 kg/m^3

Particle density:

$Ca(OH)_2$	2230 kg/m^3
$CaCO_3$	2711 kg/m^3

Particle size distribution:

$Ca(OH)_2$: aerodynamic separation

greater than	200×10^{-6} m	0 %
	90	0.8 %
	63	2.2 %
	45	4.8 %
	32	12.0 %

Bahco technique

greater than	45.5×10^{-6} m	8.1 %
	30.1	12.4 %
	12.4	18.3 %
	5.6	35.3 %
	3.2	60.6 %
	2.1	82.0 %

$CaCO_3$: aerodynamic separation

greater than	200×10^{-6} m	0 %
	90	7.2 %
	63	14.4 %
	45	22.2 %
	32	25.8 %

Bahco technique

greater than	41.3×10^{-6} m	33.5 %
	27.3	40.8 %
	11.2	49.7 %
	5.1	68.6 %
	2.9	86.1 %
	1.9	94.7 %

5.3 Design data

a) Burner		
Primary air flow	m^3/s	0.73
Secondary air flow	m^3/s	3.24
Tertiary air flow	m^3/s	2.34
Core air duct	mm	193.7 x 8.8
P.F./Primary air duct	mm	300.0 x 10.0
Secondary air duct	mm	450.0 x 10.0
Tertiary air duct	mm	155.0 x 10.0
Quarl diameter	mm	648
Quarl angle	deg.	50
Duct work	mm	219.1 x 10.0
b) Additive injection system		
Bin capacity	m^3	100
Bin diameter	mm	3100
Bin overall height	mm	17000
Bin bottom slope	deg.	60
<u>Fluidization unit:</u>		
Number		1 ea.
Type		pneumatic conveyor
Air requirement	kg/s	0.0362
Pressure differential	kPa	40
<u>Feeder</u> (as per F4T 50829)		
Number		1 ea.
Type		pneumatic
Air requirement	kg/s	0.0083
Pressure differential	kPa	40

Rotary Feeder (as per F4T 50253)

Make		Steinmüller
Number		1 ea.
Size		200
Design		direct drive
Inlet		200/200
Max. capacity $CaCO_3$	kg/h	1200
Min. capacity $CaCO_3$	kg/h	148
Max. capacity $Ca(OH)_2$	kg/h	900
Min. capacity $Ca(OH)_2$	kg/h	110
Drive		4-speed geared motor
Power consumption	kW	0.15
Motor rating	kW	0.2
Motor-speed range		zero to maximum
Motor construction class		B 5

Pneumatic Ejector (as per F4T 50078)

Number		1 ea.
Size		200
Capacity	kg/h	1200/600
Line size (DN)		80
Line length	m	36.5
Air requirement.	m^3/s	0.0982/0.0753
Inlet pressure differential	kPa	90/45

Blower (as per encl. brochure)

Number		1 ea.
Type		rotary compressor
Model		RV 32 'R'
Volumetric capacity	m^3/s	0.0982/0.0753
Pressure differential	kPa	100/50
Power consumption	kW	17.5/8
Motor rating	kW	20/15
Motor speed	rpm	1000/750
Motor construction class		B3
Sound pressure level	dB(A)	80

Blower (as per encl. brochure)

Number		1 ea.
Type		rotary compressor
Model		RV 04 'K'
Volumetric capacity	m^3/s	0.0385
Pressure differential	kPa	40
Power consumption	kW	2.34
Motor rating	kW	3.0
Motor speed	rpm	2800
Motor construction class		B3
Sound pressure level	dB(A)	80

Extracted air fan

Number		1 ea.
Type		radial fan
Model		RV 015/16-30
Volumetric capacity	m^3/s	0.267
Pressure differential	kPa	1.5
Power consumption	kW	0.95
Motor rating	kW	1.5
Motor speed	rpm	3000
Motor construction class		B3

PRICING

6 - Cost Breakdown

6.1 - Basic & Detail Engineering consisting of the following:

A) Retrofit General Arrg't Drawings

B) Shop detail drawings

C) Erection drawings

D) Structural steel modification drawings

E) Upper burner platform modification drawings.

TOTAL PRICE $250,000.00

6.2 - Fabrication

	Description	Weight Kg.	Price
A)	(2) Two stage mixing burners	6,020	$45,980.00
B)	Coal fuel piping and air ducts	5,300	$44,742.00
C)	Combination oil/gas burners, valves (fuel train)	870	$31,790.00
D)	Additive dosing system	14,320	$79,979.00
E)	Instrumentation & Control for additive dosing system	400	$39,405.00
F)	Boiler retrofit work Burner tube nest Burner throat Outer casing & stiffeners	740	$11,522.00
G)	Refractory material	4,260	$ 5,335.00
H)	Insulation material	2,830	$ 3,932.00
I)	Primary painting		$ 7,315.00
	TOTAL		$270,000.00

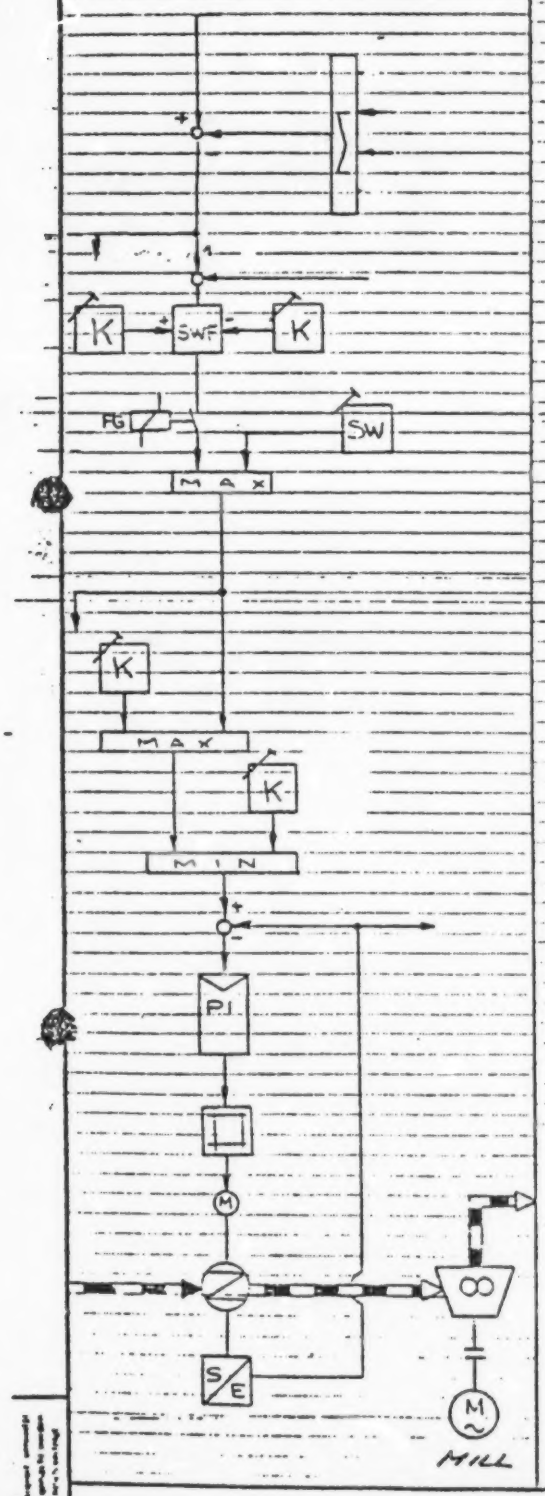
6.3 - Instrumentation and flame safeguard system Bailey or equivalent $150,000.00

6.4 - Site work and erection $200,000.00

6.5 - Project management .....$ 50,000.00

6.6 - Freight .....$ 25,000.00

6.7 - Commissioning .....$ 30,000.00



Logic	Name	Pt	Bezeichnung / Designation	Status	Kenn / Code No.	No.
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						2
						3
						4
						5
			LOAD SETPOINT BOILER			6
						7
						8
						9
						10
			FUEL FEEDER MILL 1			11
			FUEL FEEDER MILL 2			12
						13
						14
						15
			DISTRIBUTION BURNER 1/2			16
						17
						18
			OILFLOW TO BURNER	Xkg/h		19
						20
			GRADIENT ADJUSTMENT			21
						22
						23
						24
						25
						26
			START-UP SETPOINT			27
						28
						29
						30
						31
						32
						33
						34
						35
			SETPOINT MILL AIR			36
						37
						38
						39
			SPEED FEEDER	n min		40
						41
						42
						43
						44
						45
			SPEED FEEDER	n max		46
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			CONTROL MILL AIR			52
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Kennwort / Project: GAGETOWN
Gez. / Drawn: WEBER
Rel.: 622
Gepr. / Check:
Datum: 15.3.83
Revision: 1 2 3 4
Name
Datum

Auftr.-Nr. / Contr. No.: 34.6972

STEINMÜLLER
GUMMERSBACH

FUEL CONTROL
COAL

ICB 01

Blatt / Sheet 1 bis 10

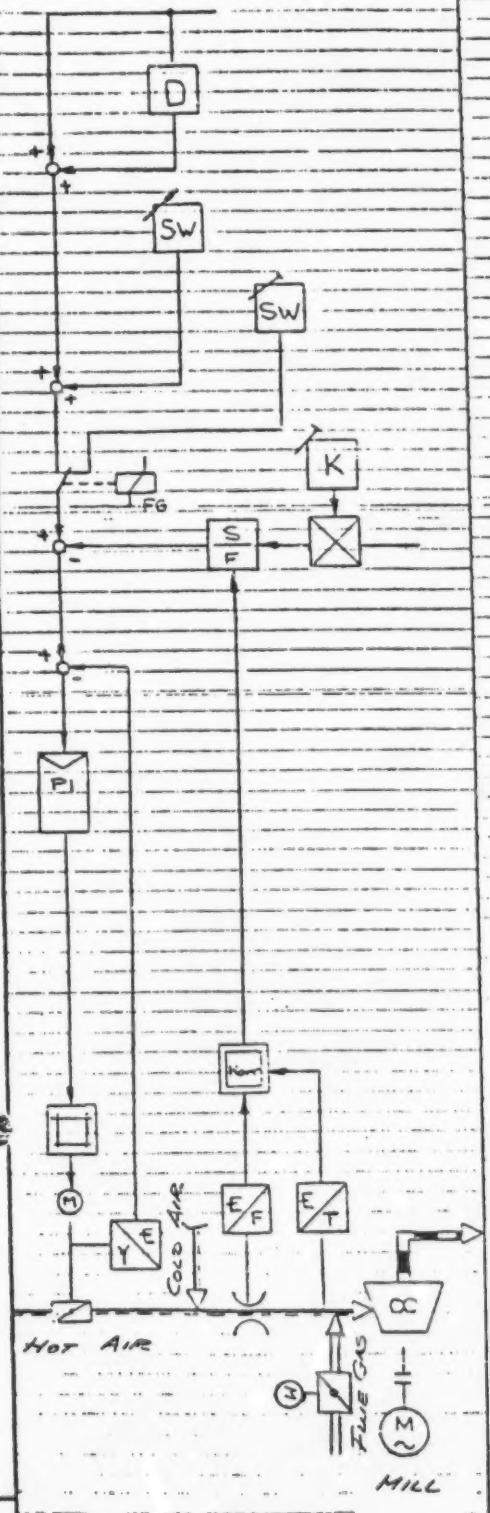
Logic | Kn. | Bezeichnung / Designation | Status | Kenn / Code No

LOAD SETPOINT MILL AIR

SETPOINT ... X %

SETPOINT X %

FEEDER SPEED



GAGETOLIN	Ges. Drawn	WEBER	Aut.	Revision	1	2	3	4
	Ges. / Check			Name				
Contr. No 34.6972	Datum	15.3.83	622	Date				

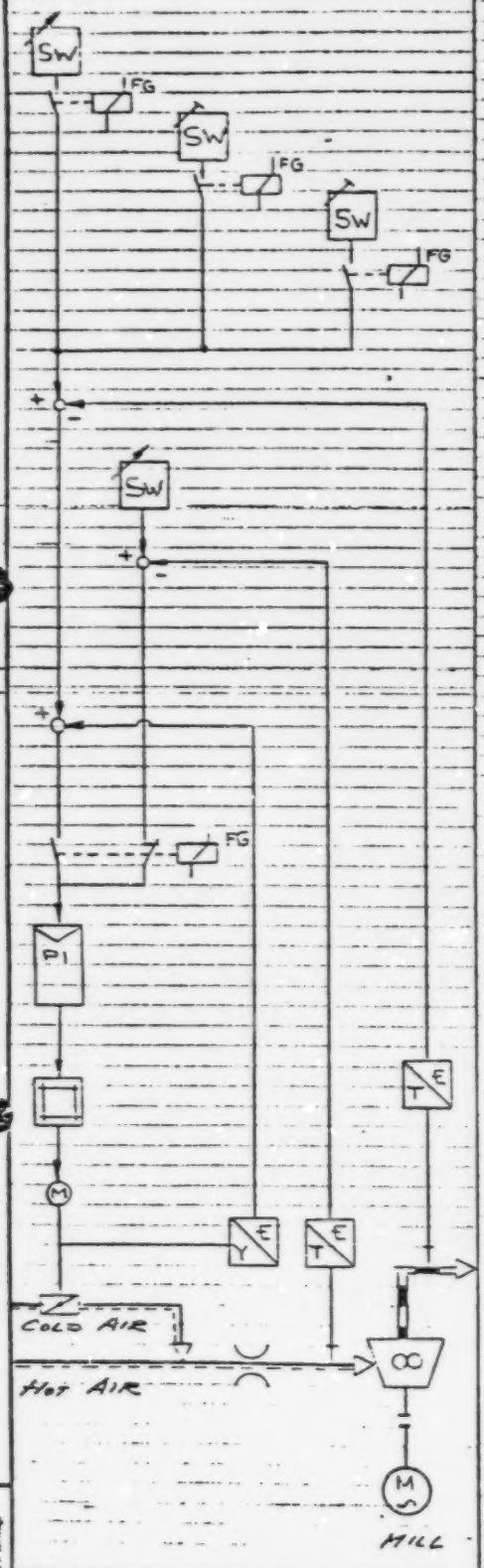
STEINMÜLLER
GUMMERSBACH

CONTROL MILL AIR FLOW

ICB 02

Sheet 2 of 10

Diese Unterlagen sind urheberrechtlich geschützt. Jede Weitergabe sowie Vervielfältigung dieser Unterlagen, Verwertung und Mitteilung ihres Inhalts ist ohne unsere ausdrückliche Genehmigung nicht gestattet. Zuwiderhandlungen verpflichten zu Schadenersatz.



Nr.	Bezeichnung / Designation	Sollwert / Value	Anmerkungen / Remarks
	SETPOINT CLASSIFIER TEMP.	X °C	
	SETPOINT CLASSIFIER TEMP.	X °C	
	SETPOINT CLASSIFIER TEMP.	X °C	
	SETPOINT MILL AIR TEMP. BEFORE MILL	X °C	

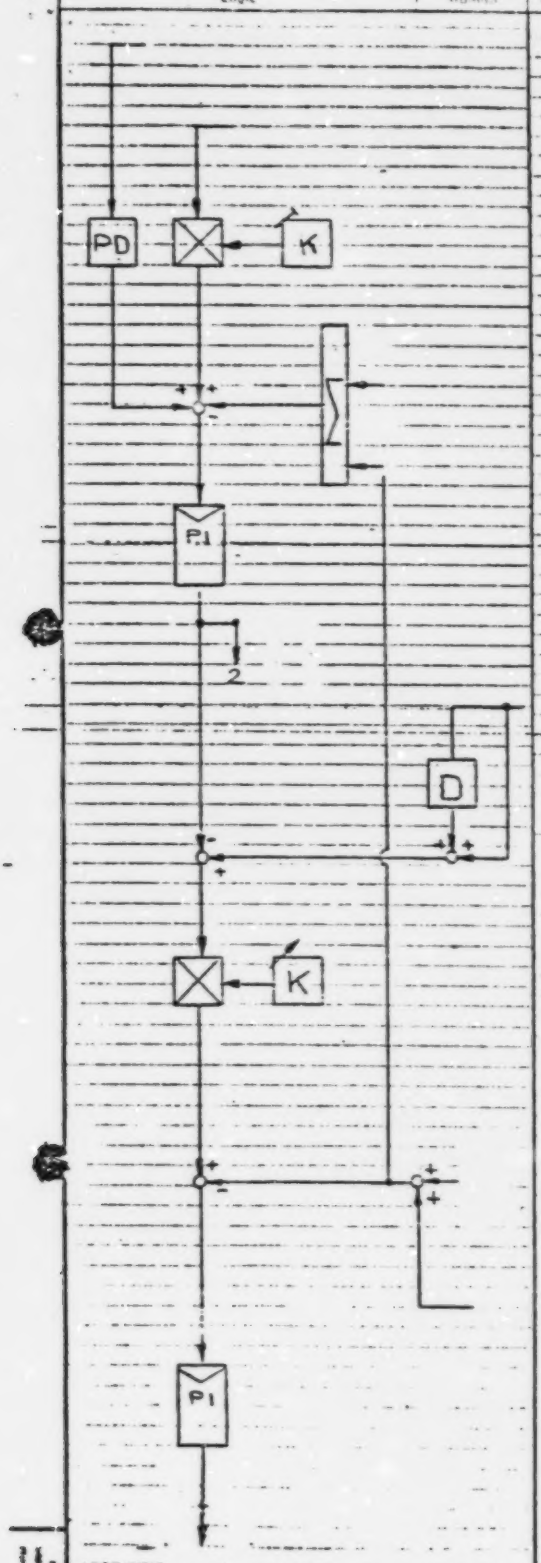
Kennwort / Project	GAGETOWN	Ges. Dieter	WEBER	Pol	Revision	1	2	3	4
Auftr.-Nr. / Contr.-No	34.6972	Ges. Check		G12	Name				
		Datum	15.3.23		Datum				

STEINMÜLLER
GUMMERSBACH

CONTROL CLASSIFIER TEMP. AND MILL AIR BEFORE MILL

ICB 03

Blatt / Sheet 3 Bl. 15



Bezeichnung Designation	Zustand Status	Kennzeichen
STEAM PRESS. CHANGES.	X. bar	
SUPERHEATED STEAM FLOW	Xt/h	
AIR. BURNER 2	nm^3/h	
AIR BURNER 1	nm^3/h	
SETPOINT AIR BURNER 1		
AIR FLOW TO BURNER 1	nm^3/h	
AIR FLOW TO MILL 1	nm^3/h	
AIR CONTROL BURNER 1		

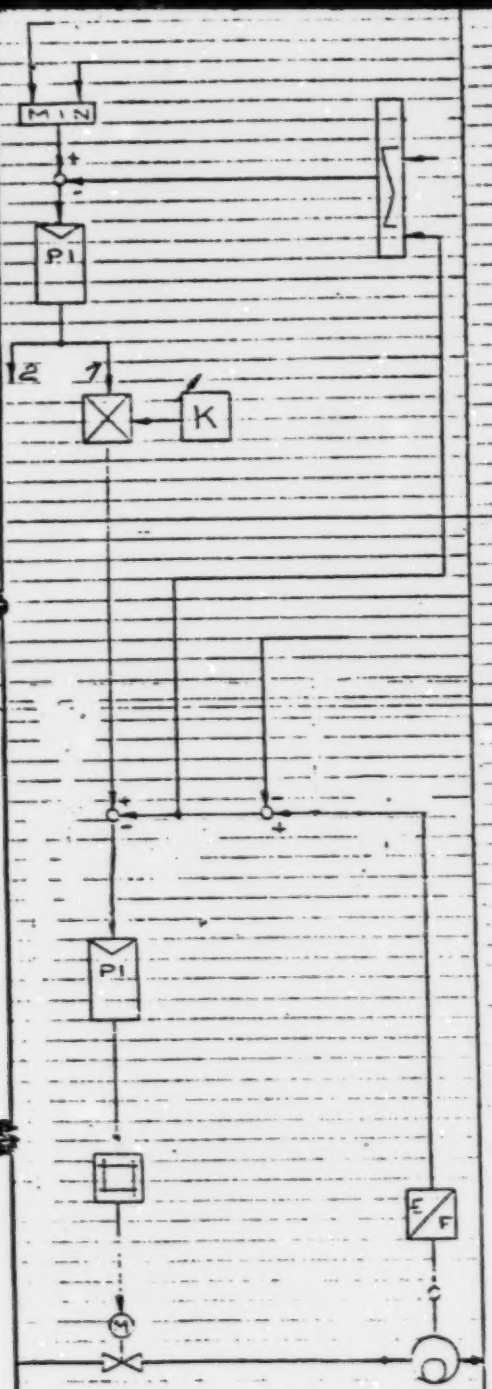
Kennwort Project	GAGETOKIN	Gez. Drawn	WEBER	Rvl	Revision	1	2	3	4
Auftr.-Nr. Contr.-No	34.6972	Gepr. Check			Name				
		Datum	15.3.83	G22	Datum				

STEINMÜLLER
GUMMERSBACH

AIR CONTROL · BURNERS

ICB 04

Blatt Sheet 4



COAL CONTROL

TOTAL COMBUTION AIR

OIL FLOW BURNER 2 X kg/h

OIL FLOW BURNER 1 X kg/h

COAL FLOW MILL 1 X kg/h

OIL FLOW BURNER 1 X kg/h

OIL BURNER 1

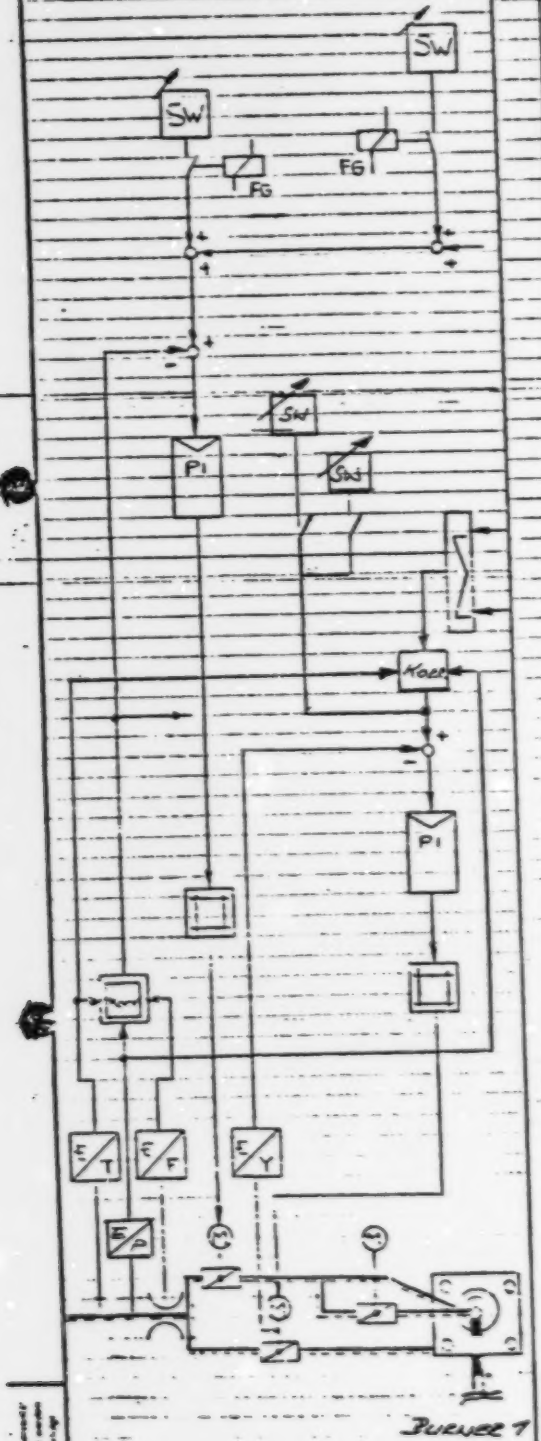
Kennwort Project GAGETOWN	Ges. Prüf. WEBER	Rev.	Revision	1	2	3	4	
Auftr.-Nr. Contr. No 34.6972	Gepr. Check	622	Name					
	Datum 15.383		Datum					

STEINMÜLLER
GUMMERSBACH

CONTROL HEAVY FUEL OIL

ICB 05

Bl. Sheet 5 Bl. 12



Logic	Kommando Kommando	Kn	Bezeichnung/Designation	Zustand Status	Kenng./Coop No
			ADDITIONAL SETPOINT COAL		
			SETPOINT IGNITION		
			CONTROL AIR FLOW BURNER 1		
			SETPOINT COAL / COAL & OIL		
			SETPOINT OIL		
			COAL FLOW BURNER 1	X kg/h	
			OIL FLOW BURNER 1	X kg/h	
			AIR FLOW CONTROL		
			SECONDARY AIR		
			CORE AIR		
			STAGING AIR		

Kunde/ Project GAGETOWN	Gez. Drawn J. WEINER	Rev	Rev-Index	1	2	3	4	
Auftr.-Nr. Contr.-No	Gepr. Check	G22	Name					
	Datum Date 15.3.83		Datum					

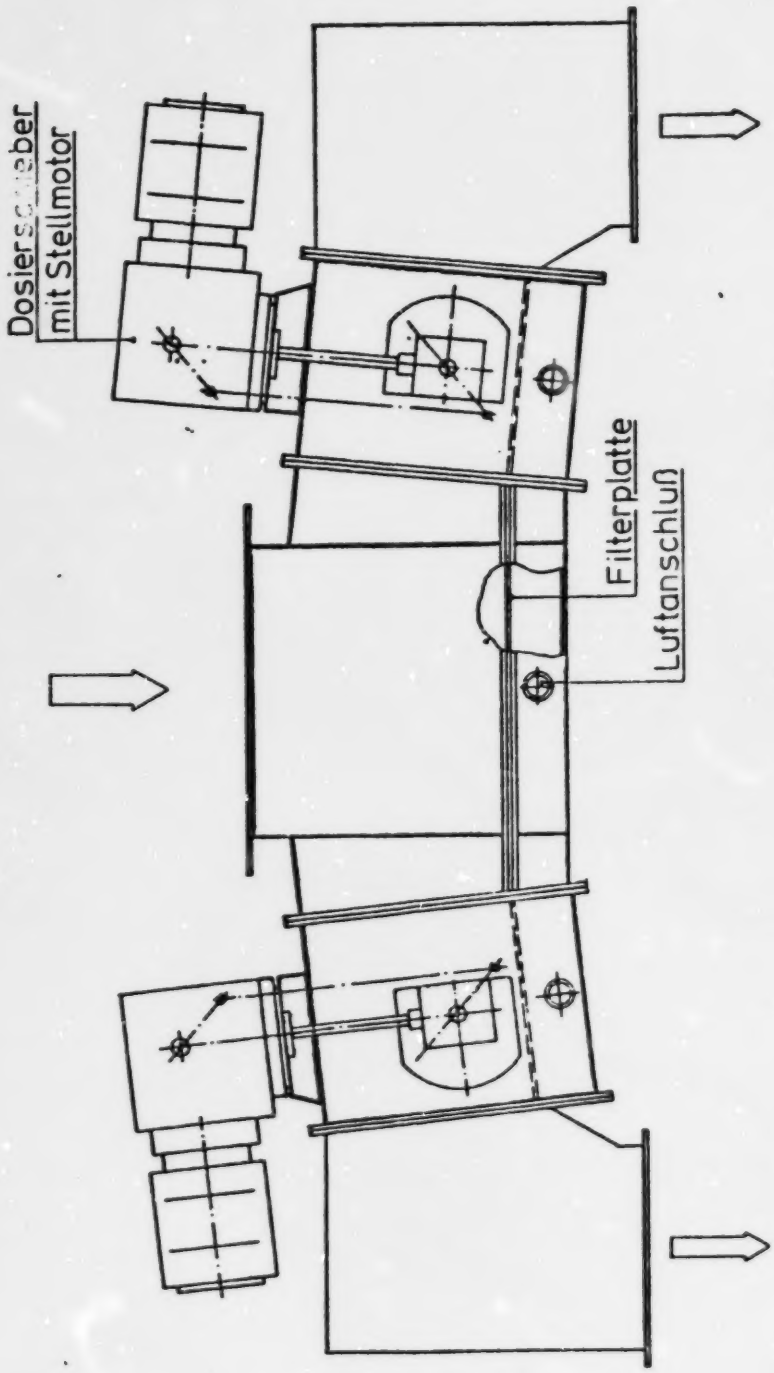
STEINMÜLLER
GUMMERSBACH

CONTROL SECONDARY AIR

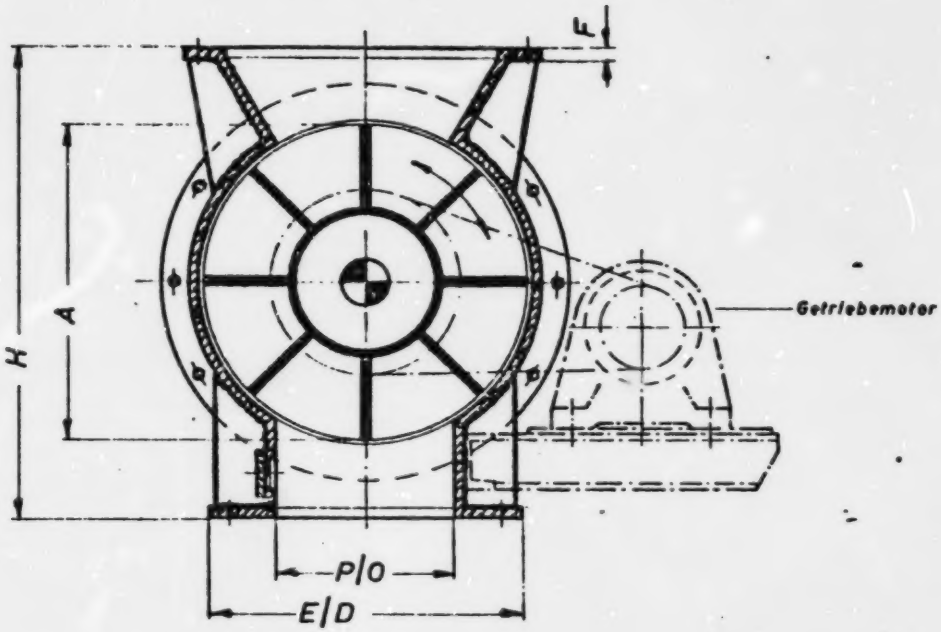
ICB 06

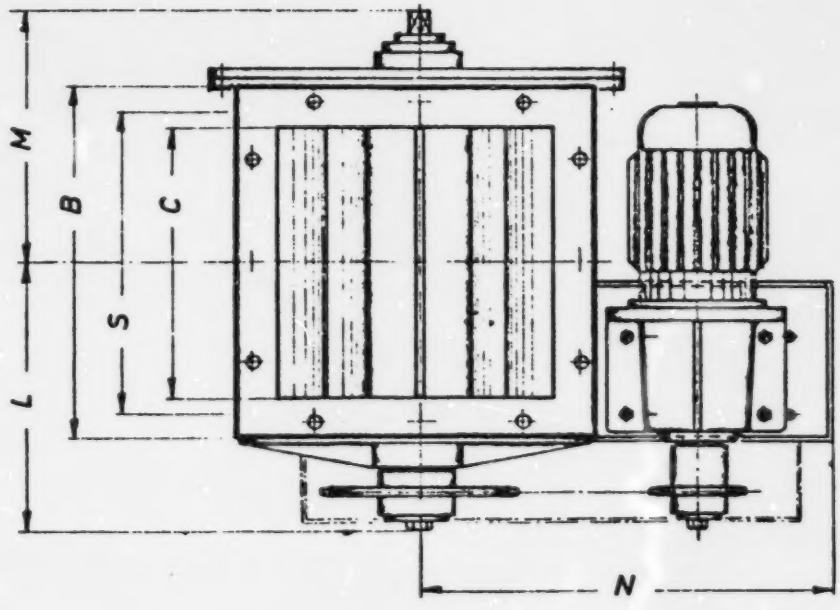
Blatt Sheet 6

Pneumatic Two Way Feeder



Rotary Vane Feeder





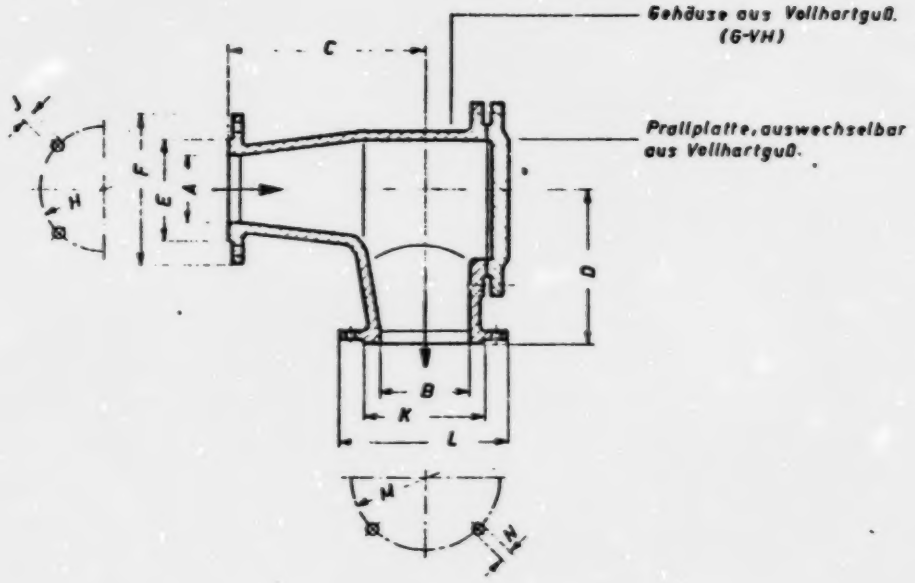
Größe	A⌀	B⌀	C⌀	D	E	F	H	L	M	N	O	P	S
200	200	300	200	320	300	8	330	520¹⁾	217		220	130	240
350	340	470	350			10	520	290	280		300	180	400
500	480	520	400	550	450	12	700	435	325	600	430	260	450

¹⁾ bei Antrieb durch Getriebe-Flanschmotor

21.68 11/4.69

Lager Nr.:	Einlaufstutzen				F4T 50109
STEINMÜLLER	Mod. od. Ges. Nr.:	Werkstoff:	Gewicht: St. -- kg	Teil Nr.: Zch. Nr.:	

Inlet Branch



Größe	A ϕ	B ϕ	C	D	E ϕ	F ϕ	H	J	K ϕ	L ϕ	M	N
50	58	64	173	165	115	175	135	4·18	122	185	145	4·18
65	68	80	165	165	122	185	145	4·18	138	200	160	4·18
80	83	100	180	192	138	200	160	4·18	158	220	180	4·18
100	104	124	280	225	158	220	180	8·18	188	250	210	8·18
125	130	150	267	225	188	250	210	8·18	212	285	240	8·23

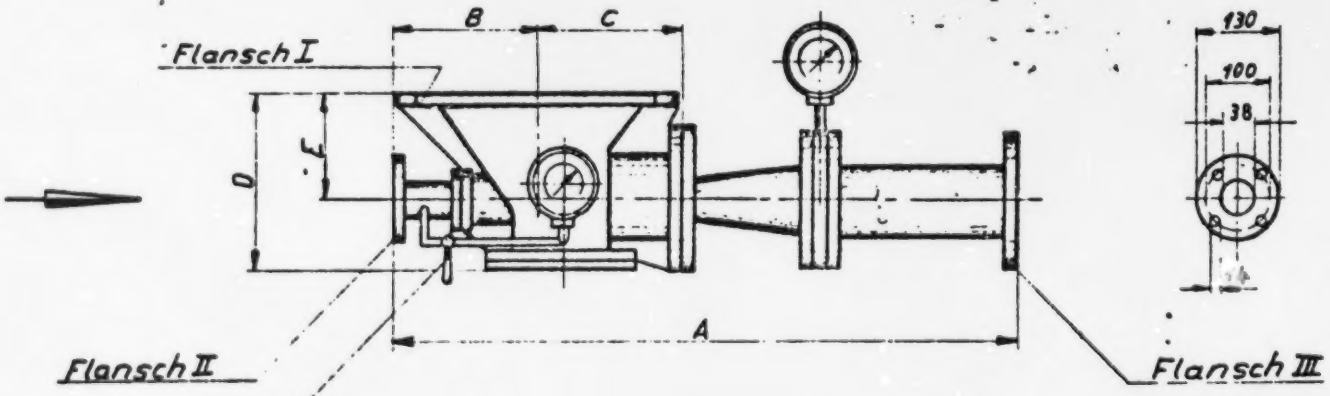
Blatt 1 FT 5006

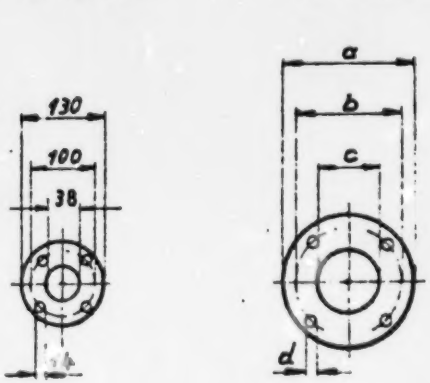
Pneumatic Ejector

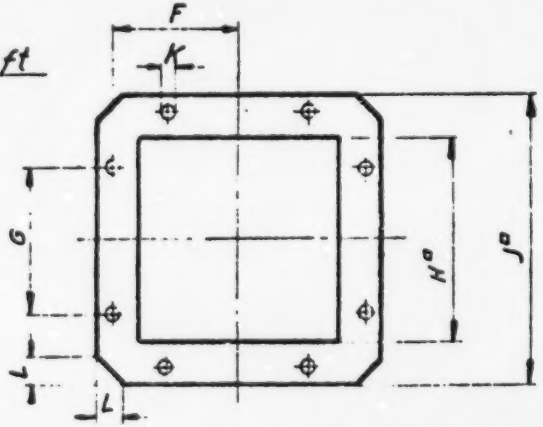
L. & C. STEINMÜLLER GMBH GUMMERSBACH

Betrifft: Förderapparat

FT 50078







Maße unverbindlich
Konstruktionsänderungen vorbeh.

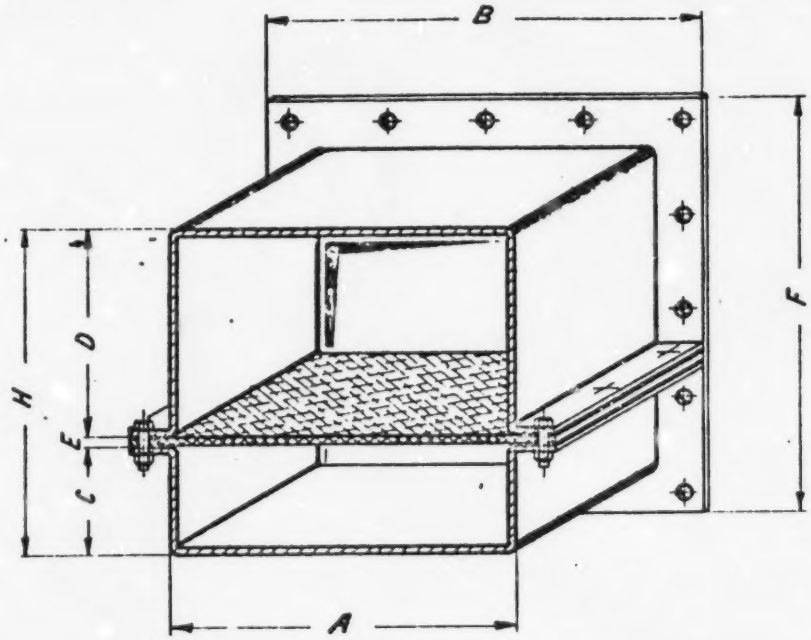
NW	Rohre DIN 2448	a	b	c	d
50	63,5×5	165	125	53	18
50	60×5	165	125	50	18
60	70×6	175	135	58	18
65	76×5	185	145	66	18
80	89×6	200	160	77	18
100	114,3×5	220	180	104	18

Größe	A					B	C	D	E	F	G	H°	J°	K°	L
	NW 50	NW 60	NW 65	NW 80	NW 100										
250	875	859	903	939	985	220	202	250	140	155	180	250	350	14	30
300	894	878	918	958	995	220	212	270	150	185	210	300	420	14	35

61

Lager Nr.:	Pneumatische Förderrinne				F4T 50077
STEINMÜLLER	Mod. od. Ges. Nr.:	Werkstoff:	Gewicht: St. = kg	Teil Nr.: Zch. Nr.:	

Fluidized Conveying Trough



Grösse	A	B	C	D	E	F	H
80	80	130	60	120	8	218	168
100	100	150	60	120	8	238	188
125	125	175	60	120	8	238	188
150	150	200	70	150	8	278	228
200	200	270	70	150	8	298	228
250	250	320	80	180	8	338	268
300	300	370	80	250	8	408	338

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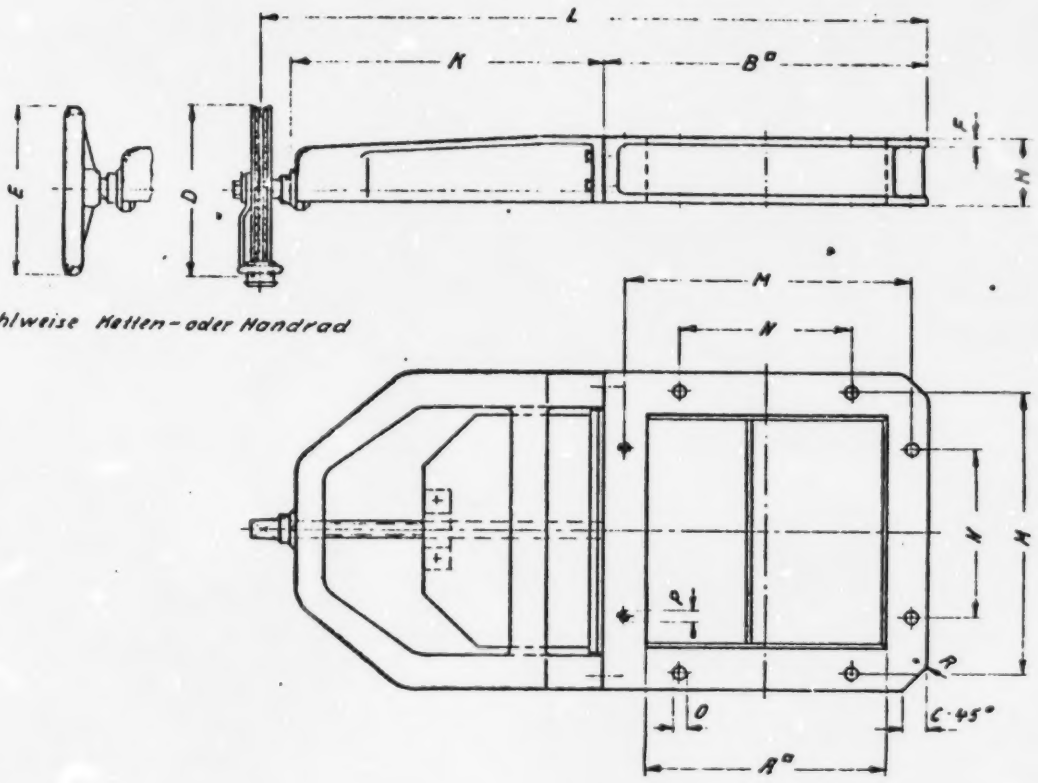
Lager Nr.:	Trichter - Absperrschieber				
STEINMÜLLER	Mod. od. Ges. Nr.:	Werkstoff:	Gewicht: St. = kg	Teil Nr.: Zch. Nr.:	F_4T 50071

SLIDE GATE VALVE

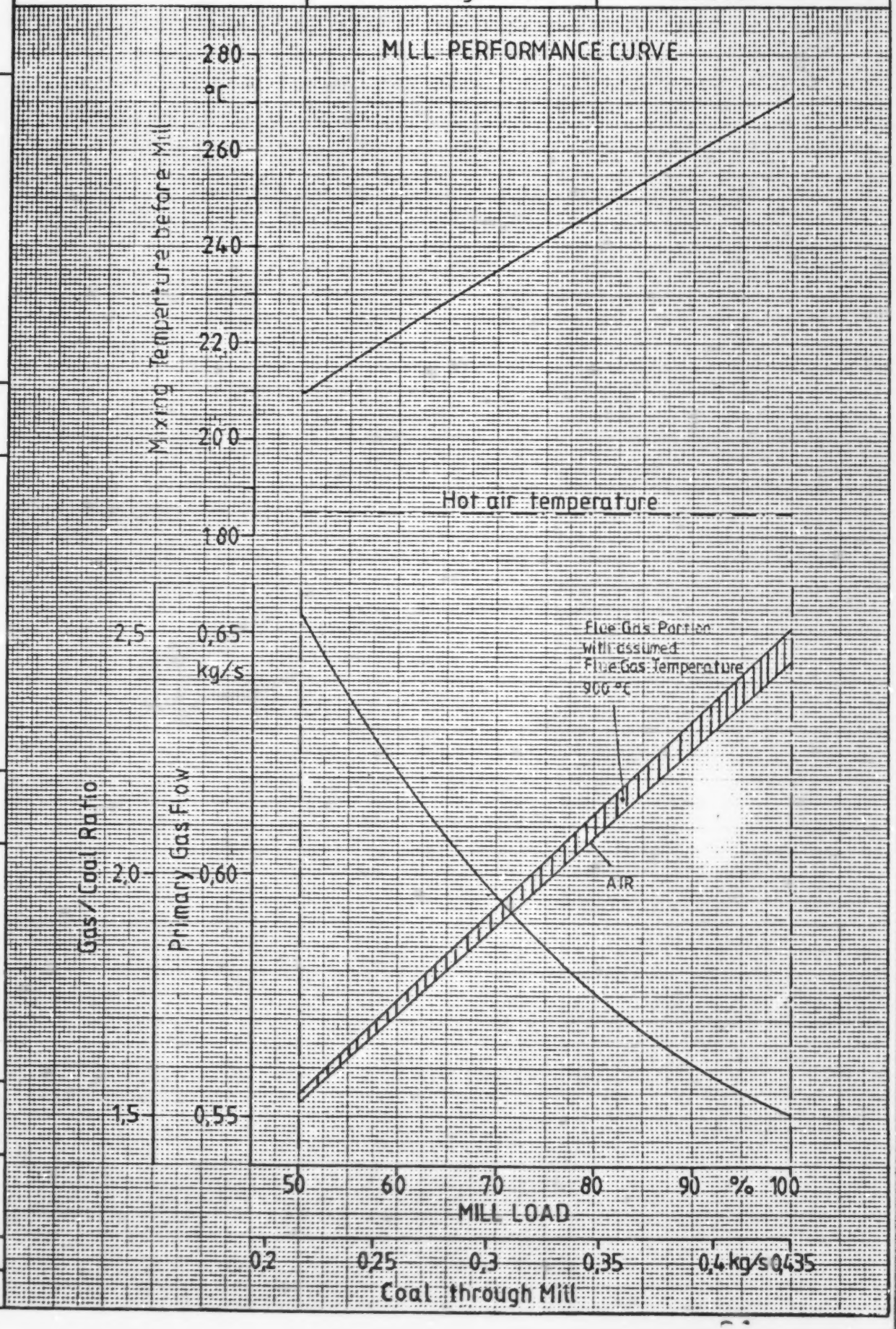


A	B	C	D	E	F	H	K	L	M	N	O	P	R			
150	250	30	210	160	10	70	239	525	210	120	14	M12	15			
200	300	30	210	200	10	70	289	625	260	150	14	M12	15			
250	350	30	210	200	10	70	339	725	310	180	14	M12	15			
300	420	35	255	250	12	80	403	865	370	210	14	M12	20			
350	470	35	255	250	12	100	455	965	420	250	18	M16	20			
400	520	35	283	320	12	100	505	1070	470	150	18	M16	20			
500	640	40	283	320	12	120	605	1290	58	200	18	M16	25			

STEINMÜLLER

Kennwort: CFB Gagetown

Datum: 25.1.83



Frühere Ausgaben:

Änderung	in	Name/Dat.

Bearbeiter: Schoe

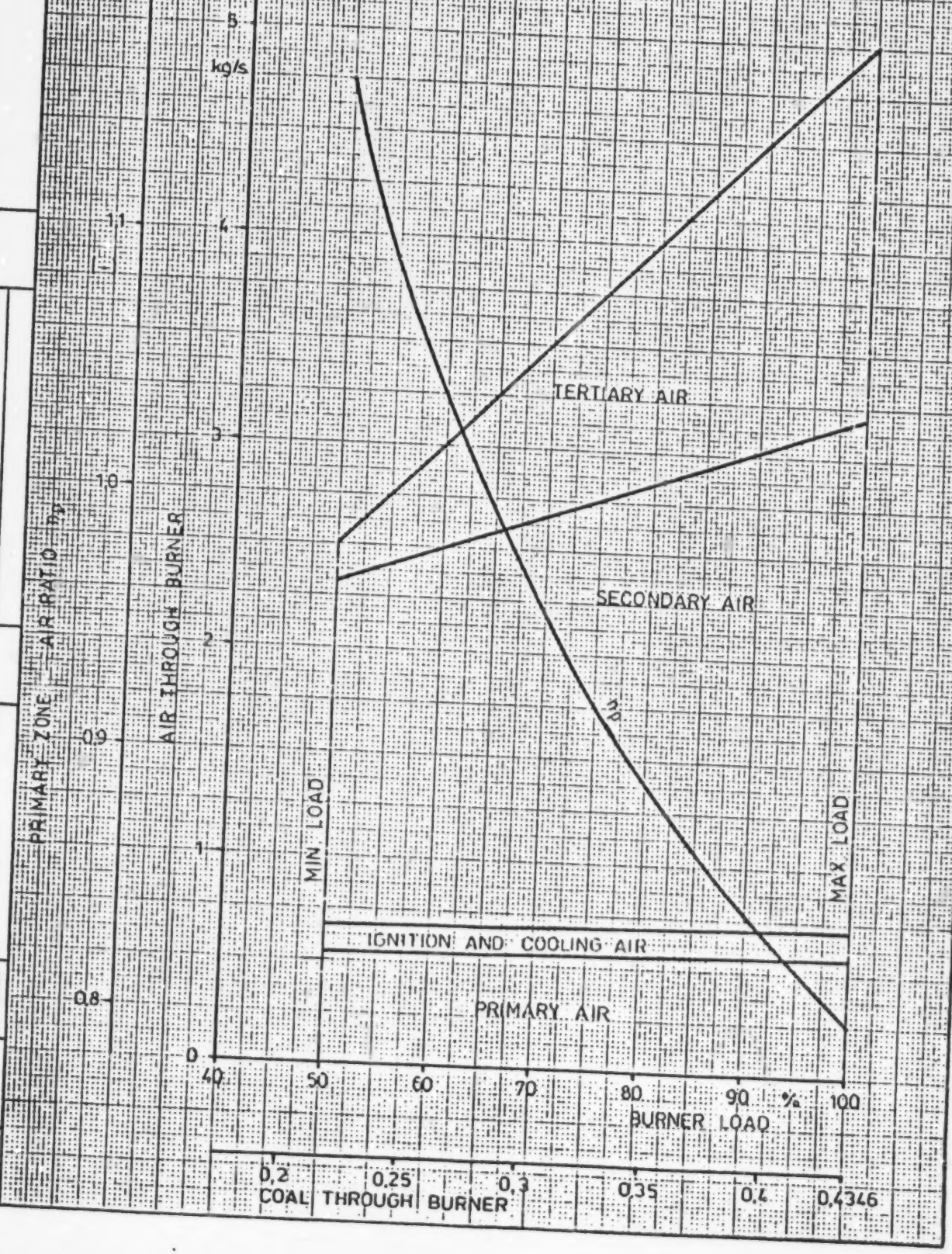
Ruf: 982

AW 131 281

STEINMÜLLER | Kennwort: 346972 | A 52

CFB Gagetown | Datum: 09.02.83

BURNER PERFORMANCE CURVE
FURNANCE EXCESS AIR RATIO = 1.25



Frühere Ausgaben:

Änderung | In | Name/Dat.

Bearbeiter: Schoe.

Ruf: 2982

STEINMÜLLER

Proj./Auftr.-Nr.	Blatt
34.6972	A 53
Kennwort	**Datum**
CFB Gagetown	09.02.83

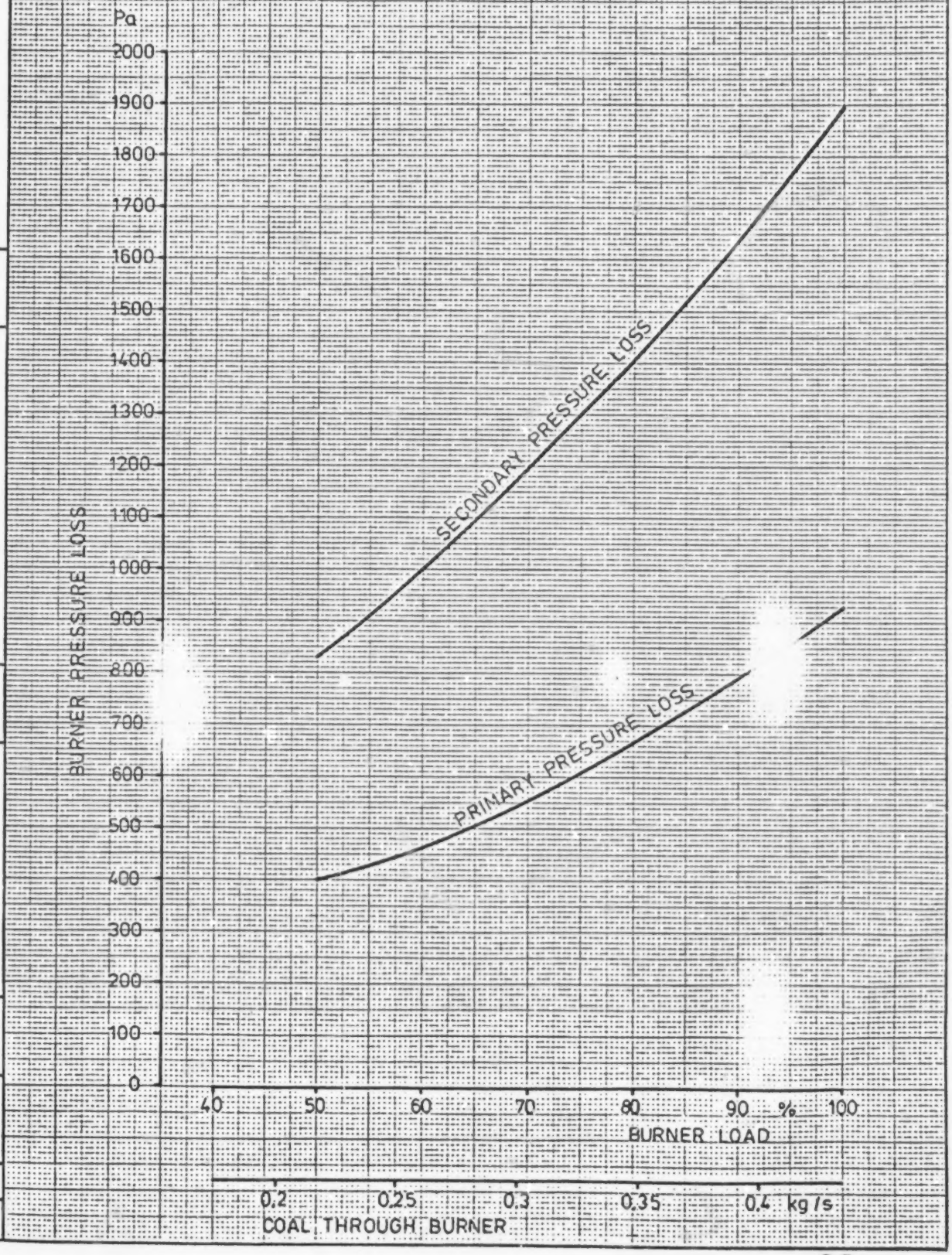
frühere Ausgaben:

Änderung	in	Name/Dat.

Bearbeiter: Schoe.

Ruf: 2982

BURNER PRESSURE LOSS



66

STEINMÜLLER

Kennwort	Datum
34.5972 CFB Gagetown	A 54 09.02.83

Änderung | In | Name/Dat.

Früheren Ausgaben:

Bearbeiter: Schoe

Ruf: 2982